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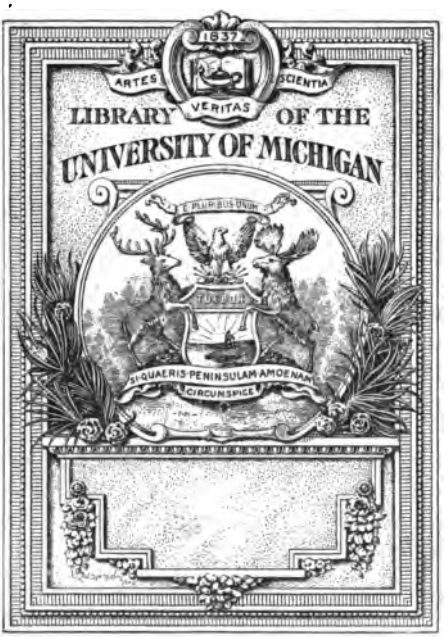
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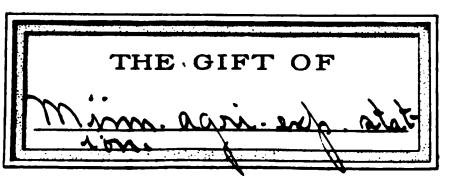
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SIXTEENTH ANNUAL REPORT

OF THE

AGRICULTURAL EXPERIMENT STATION

UNIVERSITY OF MINNESOTA

Fiscal Year, July 1, 1907, to June 30, 1908

1908

BOARD OF REGENTS.

CYRUS NORTHROP, LL.D., Minneapolis.....Ex-Officio
The President of the University.
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The HON. S. M. OWEN, Minneapolis 1913
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The HON. JOHN A. JOHNSON.
The HON. B. F. NELSON.
President CYRUS NORTHROP.
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J. A. VYE .....Secretary

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SAMUEL B. GREEN, B.S. .....Horticulturist
HARRY SNYDER, B.S.....Agricultural Chemistry and Soils
T. L. HAECKER.....Dairy Husbandry and Animal Nutrition
M. H. REYNOLDS, M.D., V.M. .....Veterinarian
ANDREW BOSS .....Agriculturist and Animal Husbandry
FREDERICK L. WASHBURN, M.A. .....Entomologist
E. M. FREEMAN, M.S. .....Vegetable Pathology
JOHN STEWART, B.S. .....Agricultural Engineering
J. A. HUMMEL, B. Agr. .....Assistant Chemist
COATES P. BULL, B. Agr. .....Assistant in Agriculture
A. G. RUGGLES, M.A. .....Assistant Entomologist
A. J. McGUIRE, B. Agr. .....Superintendent, Grand Rapids
D. A. GAUMNITZ, M.S. Agr.....Assistant in Animal Husbandry
A. D. WILSON, B.S. Agr.....Assistant in Agriculture
WM. ROBERTSON, B.S.....Superintendent, Crookston
C. C. LIPP, D.V.M. .....Assistant Veterinarian
A. D. WILHOIT, M.A. .....Assistant in Soils
L. B. BASSETT .....Assistant in Agriculture
T. P. COOPER, B.S. in Agr.....Assistant in Agriculture

The Bulletins of this Station are mailed free to all residents of this State who make application for them.

MINNEAPOLIS, MINN., July 1, 1908.

To His Excellency, John A. Johnson, Governor of Minnesota:

I have the honor to transmit to you herewith the annual report of the Agricultural Experiment Station of the University of Minnesota for the fiscal year ending June 30, 1908.

JOHN LIND,

President Board of Regents.

193402

LIST OF BULLETINS PUBLISHED DURING THE FISCAL YEAR, ENDING JUNE 30, 1908.

Pages.

Press Bulletin No. 28. 1. The Fall Web Worm a Menace to Minnesota.
2. Autumn Remedies for the Stalk Borer in Flower Gardens

Press Bulletin No. 29.—Seed Corn Shortage.

Press Bulletin No. 30.—Bearded Spring Wheat compared with Blue Stem in Minnesota.

Press Bulletin No. 31.—Suggestions to Those Contemplating Spraying.

Bulletin No. 102—Division of Agricultural Chemistry and Soils. Soil Investigations.
1. Fertilizer Tests with Wheat and Corn.
2. Influence of Fertilizers Upon the Composition and Quality of Wheat.
3. A Comparison of Chemical Methods and Field Tests for Determining the Fertilizer Requirements of Soils 2- 38

Bulletin No. 103.—Veterinary Division. Dissemination of Tuberculosis by the Manure of Infected Cattle.. 39- 64

Bulletin No. 104.—Animal Husbandry and Agricultural Divisions. Pork Production..... 65-119

Bulletin No. 105.—Division of Entomology. The Importance of the Study of Entomology. How to Collect and Preserve Insects.....119-146

Bulletin No. 106.—Division of Dairy Husbandry and Animal Nutrition. Investigation in Milk Production. The Relation of Nutrient to Product.....147-170

Bulletin No. 107.—Division of Agriculture. Corn Breeding in Minnesota.....171-256

Bulletin No. 108.—Division of Entomology. The So-Called "Green Bug" and Other Grain Aphids in Minnesota in 1907.....257-280

Bulletin No. 109.—Divisions of Agriculture and Agricultural Chemistry and Soils. The Rotation of crops. 1. Report of 10 Years on 44 Rotation Plots. 2. Influence of Rotation of Crops and Continuous Cultivation upon the Composition and Fertility of Soils 281-358

REPORT OF THE DIRECTOR OF THE EXPERIMENT STATION.

To the President of the Board of Regents:

Herewith is submitted the sixteenth annual report of the Agricultural Experiment Station of the University of Minnesota, covering the work at University Farm and the two farms at Crookston and Grand Rapids, Minnesota, for the fiscal year ending June 30th, 1908.

The report includes Bulletins 102 to 109, inclusive, published during the year, and a full account of the expenditure of the annual appropriation from the United States Government, as well as that received from the current expense fund of the University.

The year has been one of remarkable growth and many additions to the Corps and the equipment have been necessary. A division of Vegetable Pathology and Botany has been organized and established and Prof. E. M. Freeman, formerly with the Department of Agriculture at Washington, has been placed in charge. T. L. Haecker, Professor of Dairy Husbandry, has also been made Professor of Animal Nutrition and his duties and responsibilities have been accordingly enlarged. The New Main Building, provision for which was made by the Legislature of 1905, has been completed. It provides much needed executive offices and class rooms, an assembly room, a library, and quarters for the divisions of agriculture, household art, and entomology.

Because of long continued ill health, Hon. W. M. Liggett, a regent of the University from 1888 to 1905, and dean and director of the department of agriculture since 1895, resigned July 31st, 1907, and accepted a position in the agricultural division with duties proportioned to his strength. Col. Liggett, as regent and as dean and director, showed remarkable strength, was aggressive and clear sighted, and has a well earned reputation for loyal, intelligent and effective service.

A. D. Wilson has retired from work in the agricultural division to become Superintendent of Farmers' Institutes. He has an office in the Main Building which, in large measure, centralizes agricultural work at University Farm. It is believed that this closer relationship between the Farmers' Institutes and the various lines of educational and research work centering upon University Farm will be productive of good. E. C. Parker, another efficient worker in the division of agriculture, has resigned in order to meet a call from the Chinese government for service in agriculture at Mukden, Manchuria. T. P. Cooper succeeds Mr. Parker in the work here.

The last legislature made an appropriation of $76,000 for the purchase of additional land. With this money 148 acres immediately adjoining University Farm has been purchased at a cost of $72,761.33, making possible a much needed extension of general farm work.

The Adams fund, with its yearly increment, is making more research work possible each year, is giving a new impetus to original study, and is making the Station and its Corps a more important factor in the solution of agricultural problems.

THE MINNESOTA AGRICULTURAL EXPERIMENT STATION IN ACCOUNT WITH THE UNITED STATES APPROPRIATION, 1907-1908.

Dr.

To receipts from the treasurer of the United States as per appropriation for fiscal year ending June 30, 1908, as per act of congress approved March 2, 1887		$15,000.00

Cr.

By salaries	$8,483.26	
By labor		
By publications	1,038.44	
By postage and stationery	38.00	
By freight and express		
By heat, light, water, and power	1,599.92	
By chemical supplies	1.44	
By seeds, plants, and sundry supplies	360.86	
By fertilizers		
By feeding stuffs	2,082.49	
By library		
By tools, implements, and machinery	398.96	
By furniture and fixtures	123.11	
By scientific apparatus	82.08	
By live stock	416.25	
By traveling expenses	108.29	
By contingent expenses		
By buildings and land	266.90	
By balance		
	$15,000.00	$15,000.00

Dr.

To receipts from the treasurer of the United States as per appropriation for the fiscal year ending June 30, 1908, under act of congress approved March 16, 1905		$9,000.00

Cr.

By salaries	$3,595.56	
By labor	3,028.92	
By publications		
By postage and stationery	15.00	
By freight and express	11.35	
By heat, light, water, and power	128.69	
By chemical supples	11.40	
By seeds, plants, and sundry supplies	203.14	
By fertilizers		

By feeding stuffs	101.18	
By library		
By tools, implements, and machinery	411.43	
By furniture and fixtures		
By scientific apparatus	1,222.70	
By live stock	38.00	
By traveling expenses	162.72	
By contingent expenses		
By buildings and land		
By balance	69.91	
	$9,000.00	$9,000.00

FINANCIAL STATEMENT.

Statement of disbursements and receipts of the Minnesota Experiment Station for the twelve months beginning July 1st, 1907, and ending June 30, 1908, inclusive:

	Disbursements.	Receipts.	Cash Outlay.
Station	$22,707.48	$694.16	$22,013.32
Agriculture	14,221.20	1,978.34	12,242.86
Horticulture	4,744.24	744.76	3,999.48
Chemistry	1,403.12		1,403.12
Entomology	397.16		397.16
Veterinary	2,529.53	.85	2,528.68
Dairy Husbandry	142.93		142.93
Animal Husbandry	11,455.54	4,742.26	6,713.28
	$57,601.20	$8,160.37	$49,440.83
Crookston	$10,682.28	$2,682.28	$8,000.00
Grand Rapids	7,123.46	2,123.46	5,000.00
	$17,805.74	$4,805.74	$13,000.00

DIVISION OF AGRICULTURE.

Tangible results from the plant breeding nursery have been obtained during the past year. Several very promising varieties of grains developed from that source are now being increased for distribution. Minnesota No. 2 rye was given a somewhat extended trial at various points in the state during the year with very gratifying results. The average yield from the acreage grown was 27.2 bushels per acre, while the common varieties of rye grown under similar conditions averaged only 17.7 bushels per acre. The increase in yield of this selected rye is 9.5 bushels per acre. About 800 bushels of No. 2 rye was grown in the state and it is believed that every bushel will be sold for seed this fall.

Progress has been made during the year also, in increasing a hardy variety of winter wheat and sufficient stock should be on hand within the next year or two to provide for wide distribution. It is now on trial in three sections of the state.

From funds appropriated by the legislature for plant breeding work, twelve corn breeding stations have been established where varieties are being tested and an effort made to breed varieties especially adapted to the local conditions of the varying sections of the state. An experiment to determine whether or not macaroni wheat would deteriorate and become soft and starchy on our heavy, moist soils has been completed during the present year and is ready for report in bulletin form. This work has also been supported from the special appropriation for plant breeding. A bulletin on corn breeding (No. 107), has been prepared and published during the year.

The land purchased in the spring of 1907 has been surveyed and plotted for experimental work. The investigations in crop rotation on field "C" will be continued and in addition, a series of plots has been laid out on the newly acquired land for additional experiments in crop rotation and farm management. The data from the investigations on field "C" during the ten years, 1895 to 1904 inclusive, have been collected and published as part one, bulletin 109. The co-operative work in farm management carried on with farmers in the state, is also being continued as a part of the study of farm business problems.

The statistical work with the Bureau of Statistics, United States Department of Agriculture, is still carried on at the three

original statistical routes, Northfield, Marshall and Halstead. It has been supplemented somewhat by including farmers at other points in the state who are following specialized types of farming. The results of six years' statistics on cost of production have been put in bulletin form, and are now with the Bureau of Statistics for publication. Mr. T. P. Cooper, a graduate of the College of Agriculture, 1908, has been put in charge of the work.

In addition to the publication of bulletin 107 and part one, bulletin 109, the members of the force in the Agricultural Division have aided in preparing copy for a bulletin on plant breeding and one on farm management. This copy is now in the hands of W. M. Hays, Assistant Secretary of the United States Department of Agriculture, for publication as a joint bulletin.

DIVISION OF AGRICULTURAL CHEMISTRY AND SOILS.

From the division of agricultural chemistry and soils two bulletins have been issued. No. 102 gives the results of soil investigations and co-operative fertilizer tests conducted in different parts of the state. Part two of Bulletin No. 109 discusses the income and outgo of fertility when soils are subjected to different systems of rotation and cropping,—those investigations were inaugurated at University Farm in 1894, in co-operation with the agricultural division of the station, and the bulletin gives the results of the first ten years' work.

Investigations now in progress are along the lines of human nutrition and soils as outlined in former reports. An investigation has also been undertaken relative to the production of denatured alcohol under farm conditions and a small domestic still has been imported from France. As in former years a large number of chemical analyses have been made for other divisions of the station and numerous free analyses for farmers and citizens of the state.

DIVISION OF ANIMAL HUSBANDRY.

The Experiment Station herds have been maintained during the past year at the usual standard. A few choice animals have been purchased and added to the breeding herd. The increase from the herds and flocks has been used in various feeding experiments when they could be properly classified, and the surplus

stock sold either as breeding stock or to the butchers for meat. Work with forage crops for sheep and swine has been continued and extended. Ten acres of the Hendrickson land recently purchased has been fenced for permanent hog lots and paddocks in which to conduct experiments in growing forage for swine. This arrangement allows more room for the sheep in the old quarters and has given relief in a decidedly cramped division. Studies of maintenance rations for brood sows and also for ewes have constituted the major part of the feeding experiments during the winter. During the summer season and through the fall the experiments have largely been on the production and pasturing of forage crops and in experiments on hogging off corn. The results from the experiments in hogging off corn and in the field management of swine were published during the year in bulletin No. 104, for which there has been such a demand that the supply printed was inadequate.

The milking shorthorn experiment which was started a year ago in co-operation with the Bureau of Animal Industry, United States Department of Agriculture, is finally organized with a circuit superintendent in charge and with four herds now under regular record and test. These tests include the milk and butter fat yields and an approximate record of the feed consumed. The object of the experiment is to demonstrate the possibility of organizing the people of a state or community in a co-operative movement to improve a specified class of stock along lines of intrinsic value. The experiment is of national importance and is being closely followed by the United States Government and the Dominion of Canada.

DIVISION OF DAIRY HUSBANDRY AND ANIMAL NUTRITION.

In this division the investigation conducted for a series of years in the nutrient requirements in milk production was practically completed at the close of the winter's work in feeding experiments, and data covering fourteen winters' work are being compiled for publication. The deductions made from the feeding operations carried on with the dairy herds in the St. Louis dairy cow demonstration, where a complete record was kept of feed consumed by each cow and dairy products yielded, have been published in bulletin No. 106. The results obtained have proven

very valuable as they have a direct bearing upon the work carried on at this station in studying the relation between nutrients consumed by dairy cows and milk solids yielded.

The feeding experiments conducted in this division have resulted in the formulation of a scientific and practical feeding standard for milk production adapted to the needs of cows of any size and yielding any quantity and quality of milk. By the use of this standard in feeding for milk great saving can be made in cost of production and a large increase in yield secured.

It was planned to make a more comprehensive and final study of the composition of milk and this final work was inaugurated in the fall of 1907, but because of lack of equipment and help in this and in the chemical division to do the large amount of work involved, it was abandoned.

The new work in Animal Nutrition assigned to this division was inaugurated early in February by setting aside eight steer calves that were in the herd, the purchase during the month of twenty-two new born male calves, beef bred, and later the purchase of thirty male calves similarly bred and dropped the latter part of May. The investigation in animal nutrition will require some twelve years of the most painstaking and skilful work, to which the chief of the division will in the course of a year devote all his time. It will also require the services of one analyst for the current year. By the close of the fiscal year six animals had been slaughtered for analyses, all samples reduced to water free substances and samples delivered to the chemical division for analysis.

During the year the new barn for the division has been erected and the stalls and other furnishings are expected to be in place by the time stall feeding begins. The nutrition work assigned to the division will require provision for considerable more barn room, details of which will be submitted in due time.

A bulletin is now being prepared covering the experiments made from 1894 to 1908, upon the nutrient requirements in milk production.

DIVISION OF ENTOMOLOGY.

More than the usual amount of research work has been accomplished during the year, as indicated by the press and station bulletins, and circulars issued. Press Bulletin No. 28 was issued

last fall, treating of the web worm and the stalk borer; the former a caterpillar which eats the foliage of shade trees and shrubbery, and the latter a serious pest in flower and vegetable gardens. Press Bulletin No. 31 was issued later, giving recipes for various spraying compounds, classifying the pests under the heads of plants affected, and giving directions for their treatment. Crown gall on raspberries seems to be increasing in Minnesota. A circular has been issued upon that disease, indicating how best to eradicate it.

Experiment Station Bulletin No. 105, entitled "The Importance of the Study of Entomology, and How to Collect and Study Insects," was issued in February. This was sent to all schools throughout the state. In April, Experiment Station Bulletin No. 108 was issued on the so-called "Green Bug," and other grain aphids. Circulars on remedies for the cabbage maggot, which we very generally mailed to market gardeners and to the press, were issued, as well as a circular on Hydrocyanic Acid Gas treatment for the flour moth, which was mailed quite generally to millers in Minnesota.

A goodly number of insects have been named for the Minneapolis Park Board, advising certain remedies in connection therewith.

Under the provisions of the Adams law, work is being done upon the life history of and remedies for Brucophagus funebris, which affects the clover crop. Work is also being done with Macrosiphum granaria, affecting wheat; and with the leaf hopper, Emposca mali. In the insectary a large number of experiments are being carried on to determine as many points as possible in the Binomics of insects. The maple tree borer, the locust borer, the ash tree borer, the stalk borer, referred to above, and the bee moth, as well as various lice affecting grain, may be mentioned in this connection.

Communications have been mailed to the press from time to time. One of these gave remedies for black flies when affecting stock, these having been especially troublesome this summer; another showed how to deal with ants in the house and garden; and a third gave particulars regarding the Oak Tree Pruner, which sometimes attacks apple as well as other trees.

Experiments on the maggot, known as Pegomyia brassicæ, which attacks the roots of cabbages and growing radishes and

turnips, have been continued this season, as well as observations on the so-called "Green bug." A very thorough experiment on the use of Arsenate of Lead against the Plum Curculio has been carried on as well as experiments showing the comparative merits of liquid and dust spray. Assistance has been given to citizens in various parts of the state in destroying grasshoppers, tree borers, and other pests as occasion has demanded.

DIVISION OF HORTICULTURE AND FORESTRY.

The work in the Division of Horticulture and Forestry has been along a variety of lines during the past year, and much the same as in preceding years. The establishment of the fruit breeding farm at Zumbro Heights gives us a much needed opportunity for testing out our seedlings. This marks a great advance in our plant breeding work, and is destined to produce important results. There are about 78 acres of land in this farm, and we have erected there during the past season one dwelling house (24x24), with greenhouse (20x50) attached, one concrete storage cellar (20x50), one hip roof barn (30x40) with lean-to for carriages, and one 6-inch well, 250 feet deep. It is proposed to underdrain a few spots that seem too wet for profitable horticulture. This work is now going on.

Mr. A. R. Kohler has carried on an interesting line of investigations with potatoes, including tests of varieties and a comparison of seed potatoes of our own raising with those from other sections, and in co-operation with Prof. Freeman has made a study of the potato diseases and the best way of combating them. He has also raised about 8,000 seedling potatoes.

Experiment work in forestry is not what it should be, owing to a lack of funds, and with the present means available, experiment work cannot be undertaken in a manner commensurate with the importance of the forest wealth of this state. However, in Itasca Park experiments are being carried on in studying the best method of making firebreaks and of accurately measuring standing timber. Experiments have also been made to determine the best way of sowing pine seeds, and some interesting results obtained.

The experiment work, heretofore in charge of Assistant Prof. S. B. Detwiler, will now be carried on under the direction of J. P. Wentling, Prof. Detwiler having resigned to accept a position as forester with a Minnesota lumber concern.

Experiments will be undertaken in the treatment of the quickly perishable woods with creosote, for the purpose of showing the value of open tank treatment for fence posts. This is destined to lead to very important results.

DIVISION OF VEGETABLE PATHOLOGY AND BOTANY.

This division began formal work in January, 1908. The work of organization and equipment of laboratories has naturally occupied considerable time. Work on the diseases of economic plants has been planned and field work is being carried on.

A survey of the plant diseases of Minnesota has been undertaken. This important field, which necessarily underlies the future work of the division, is receiving careful attention. It is planned to thoroughly canvass the diseases of all economic plants in the state and to collect specimens for illustration and reference. This work will give a basis for the future work in the division. Identification of many plants and plant diseases has been made for farmers throughout the state.

The work in rust and smut of wheat and other grains, begun by the head of the division while in charge of this work for the United States Department of Agriculture, has been continued at this station, with the co-operation of the Federal Department. Vital points in the life history of the rusts, chiefly of wheat and oats, are under investigation and some promising work in rust-resistance of wheat has been begun.

The smuts of cereals, especially the loose smut of barley and wheat, which are becoming serious pests in this state, have been thoroughly investigated and practical treatments devised. Varietal resistance of cereals to smut has likewise been tested.

Work has also been commenced along the following lines: the cause and prevention of blight of oats; the prevention of damping-off of coniferous seedlings by various treatments; the cause and prevention of potato rots; collection of seed and plant samples of weeds of the state for demonstration work, to enable the farmer to recognize noxious weeds; plans for work in eradication of weeds; the development of biological features of research in timber rotting to assist in the investigation of preservation and treatment of wood.

An isolated field for disease work of field and garden plants has been planned for immediate use.

XVI

VETERINARY DIVISION.

HOG CHOLERA.

Twenty-four shoats have been used in a vaccine experiment. Sixteen were taken to horse stalls at the Fair Grounds adjoining the University Farm. Eight were left at the Experiment Station. It was the purpose to send these eight out to farm outbreaks in pairs, one vaccinated and one check. Favorable conditions did not develop and but one pair was sent out. Neither of this pair died nor was seriously sick so that this portion of the experiment gave no information.

FAIR GROUNDS EXPERIMENT.

Of the sixteen taken to the Fair Grounds, eight were given the "simultaneous" vaccination November 23, 1907, and confined in Stall 14, with three checks. The purpose of this was to get information concerning the probability of spreading the infection by this method of vaccination. The eight vaccinated pigs were closely observed and apparently received the vaccination without any unfavorable effect. The unvaccinated checks associated with them showed no evidence of hog cholera at any time, so that so far as this experiment is concerned, there is some evidence to indicate that the disease is not liable to be spread by vaccination.

In Stall 10, there were placed three pigs inoculated November 23, 1907, with the virulent blood used in vacinating those in Stall 14, and two checks. The three inoculated pigs in Stall 10 soon developed hog cholera and died as did later the two checks placed with them, indicating a high degree of virulence for the blood used in vaccination and against which the serum protected the eight vaccinated shoats.

UNIVERSITY FARM OUTBREAK. EXPERIMENTAL WORK, FEBRUARY 1 TO MARCH 20, 1908.

A severe outbreak developed among the hogs on the University Farm, fortunately under conditions where it was quite evident that there was no connection between this outbreak and the experimental work. On February 1st, a lot of sick University Farm hogs were divided into three pens, the pens presumably being thoroughly infected. Into each one of these pens there was placed one "simultaneous" vaccine shoat, one "serum only" shoat, and one check. After exposure for several weeks, the vaccinated pigs

were all alive and thrifty, never having been sick. Two of the checks died. In this outbreak, twenty farm hogs died.

CARLING FARM EXPERIMENT. EXPERIMENTAL WORK, APRIL 3 TO JUNE 15, 1908.

During the latter part of March there developed a severe outbreak of cholera on a farm within two miles of the University Farm. This farm had originally forty-two hogs and lost thirty-nine during the outbreak. Five had died prior to April 1st. Careful autopsies showed undoubted hog cholera. Lot "A" refers to eighteen shoats, several of which were evidently sick, selected for this portion of the experiment and placed by themselves in the horse barn. Lot "B" refers to sick hogs running in a large yard where a number of hogs had died, having a good shed and shelter in which there had been much sickness. Lot "A" was divided into two groups, each group containing an equal number of sick and well hogs. One group was vaccinated with "serum only" and the other group left untreated. The shoats were properly ear-marked and then put together in the horse barn already mentioned, ten vaccinated, eight checks. On April 2nd, two "serum only" and two "simultaneous" vaccine experimental shoats were placed with these. Of the eight unvaccinated Carling shoats in lot "A" seven died. Of the ten vaccinated Carling shoats in lot "A" nine died. The three previously vaccinated University Farm experimental shoats continued in perfect health to the end of the experiment. Of the vaccinated hogs that died there were two that showed purulent pneumonia without plain lesions of hog cholera. Of the unvaccinated hogs that died, there were three that showed purulent pneumonia without plain lesions of hog cholera. The University Farm "serum only" experimental shoats, sent over to the Carling outbreak, were vaccinated on February 1st, 1908. The "simultaneous" shoats were vaccinated November 23rd, 1907. During the work with lot "A," one hog died and was eaten by the others. This was, of course, unintentional on the part of those conducting the experiment. What effect this may have had in increasing the loss among the "serum only" vaccinated Carling hogs may only be a conjecture. Certainly it did not harm the vaccinated experimental hogs.

Lot "B" was composed of seven sick Carling hogs having access to a good shed and running in a large field. Into this lot two "serum only" and one "simultaneous" University Farm experi-

mental shoats were placed. The Carling hogs in this lot all died. The total deaths of Carling hogs in this lot, including those alive at the beginning of the experiment and those previously dead, were sixteen. The three experimental pigs were unharmed, growing rapidly and apparently doing unusually well. The seven experimental hogs were returned on June 15th, 1908, from the Carling farm to the University Farm and have since remained in perfect health. They are to be used for hyperimmunizing in the production of serum. Pens and equipment in general are ready and the production of the Dorset-Niles serum is being carried on in a small way for Minnesota. Experience with this vaccine has been exceedingly satisfactory so far as the vaccination of well hogs is concerned. It has been used in only one lot of hogs already infected, some of which were sick, where the results were unsatisfactory. (Carling Lot "A"). This would hardly seem to operate to the serious discredit of the vaccine. Because of lack of funds, the vaccine can be produced on a small scale only. To the extent of the supply, it is the plan to furnish vaccine this season free of expense making the practical use of it through field veterinarians of the Live Stock Sanitary Board.

VENTILATION.

Manuscript for two bulletins for technical series and for annual reports, has been completed. The first of these, Ventilation Bulletin No. 2, presents a full statement of the actual work and results upon which a preliminary bulletin, No. 98, was based. It includes a great amount of very careful work with blood, urine, air, with blood of the confined animals and the air of the ventilation stalls. It also includes a careful study of pulse, temperature, respiration, stall moisture, and the various other data which give information concerning the actual stall conditions and effect upon the confined animal. The second of these two manuscripts, or Ventilation Bulletin No. 3, covers similar work for a different set of experimental animals. A number of additional features were taken up for study so that there is in Ventilation Bulletin No. 3, a duplication of work previously done for Numbers 1 and 2 to check with results obtained in the earlier work. This work with a second set of animals was more thoroughly done and with a number of additional features and confirms fully the suggestions and statements made in Bulletin 98.

Plans for this summer, especially with blood and urine and milk flow, has been interrupted by very hot weather and unexpected high stall temperatures. We have substituted another line of work with light and dark stalls, studying the physical changes in the animal when confined in light and dark stalls, both being well ventilated. The essential purpose of all this ventilation work is to ascertain definitely whether domestic animals are actually injured by lack of ventilation or light in the absence of infectious disease, and if so, how and where. The next item for determination is the least amount of ventilation actually necessary for health and comfort and profitable feeding or milking. The entire work thus far has been in studying effects upon the confined animals. It seems quite evident that some of these things should be known before we attempt to study plans for stable ventilation. Things have already been clearly demonstrated in the course of this work which upset previous teachings concerning stable ventilation.

SWAMP FEVER.

This work has been continued during the past year as hitherto under financial support from the United States Government. This work is under a co-operation agreement between the Federal Bureau of Animal Industry, Experiment Station, and Live Stock Sanitary Board. During the past year, there were only four stalls that could be safely used for work with a serious infectious disease. These stalls have been constantly full, with a number of horses waiting to take the place of those which die of the disease in the course of the work. In connection with the Sanitary Board, an additional seven-stall and feed room building is being constructed which will give eleven stalls in which thirteen to fifteen horses can be used simultaneously. The chief problems studied this year have been the specific cause of the disease. The disease has been reproduced repeatedly by blood inoculation, passing the disease in this way through several animals in succession. In this way it has been clearly demonstrated that the cause of the disease is a living virus or infection and not a mere poison. It has also been demonstrated that certain intestinal parasites of horses which have been supposed to be the cause of the disease can play but a minor part at the most. Another feature of the work done has been in connection with susceptibility. An effort has been made to determine what animals are susceptible to the disease and therefore capable of spreading it; also to find some

laboratory animal susceptible to the disease which could be cheaply used in place of horses for a portion of the work. In this feature we have not been successful as all the common laboratory animals appear to resist this disease. Some evidence has accumulated to the effect that mules are less susceptible than horses. If proven true, this will be important information for certain portions of the state.

Common Methods of Spread: As soon as the new stalls are completed, it is hoped to accumulate information rapidly concerning the ways in which this disease spreads from animal to animal and from farm to farm whether in feed, water, or air-borne. Careful clinical records have been kept of all cases developed during the year and thus valuable information concerning the history and development of this disease is being secured. Efforts are being made to determine the cause of the disease; its methods of spread; susceptibility of different animals; methods of body infection; and finally a preventative serum or vaccine.

TUBERCULOSIS DISSEMINATION.

Studying methods of dissemination for this disease has been a continuation of the work published in Bulletin 103, "Dissemination of Tuberculosis by the Manure of Infected Cattle." By special arrangements with the Inspector in charge and a Sanitary Board veterinarian at South St. Paul, it is possible to collect material for this work, easily, cheaply, and from very large numbers of cattle. We have been using tuberculous cattle sent to South St. Paul for slaughter in the course of the State Live Stock Sanitary Board work. Information is received in advance when tuberculous cattle are coming in for slaughter. A local inspector of the Sanitary Board at South St. Paul secures the necessary material for this division without expense. This is a very marked improvement over the plan by which the work was done for Bulletin No. 103. It gives information for a very large number of cattle at a minimum expense. The seriousness of this question of scattering tuberculosis in the manure of tubercular cattle seems to justify continuing this work until full information is secured. Tuberculosis is scattered by the very easy and common infection of cow's milk with particles of dried manure and the possible infection of the people who consume this milk and by dried manure which may easily become pulverized and float in the air to be inhaled by susceptible cattle and possibly by stable attendants.

The first set of experimental demonstration work with the von Behring anti-tuberculosis vaccine has been practically completed. Calves that were vaccinated a year or so ago together with check calves (young cattle not vaccinated but exposed to similar opportunity for infection) have been tested and the material may be quickly put in form whenever there is opportunity for publication. While results have not made as good a showing for the vaccine as students of the tuberculosis problem might hope, the results are nevertheless of direct and important practical interest for the cattle owner. The work done in the first series of this experiment was purposely conducted under conditions and in about the way in which an average stockman would be compelled to do it. In justice to the vaccine it should be stated that the von Behring rules were not all obeyed, it being the purpose to secure information concerning the efficiency of this vaccine where used under ordinary farm conditions. Some of the calves in this preliminary experiment which reacted under tuberculin are being held over for another year in order to see whether they will react again at the end of the year. Then in view of their tuberculin tests, history and post mortem examinations, it is expected to determine whether the reactions were due to (1) bovine tuberculosis infection in spite of the vaccine, or (2) whether possibly to vaccine infection, or (3) whether original in the calf before vaccination.

INFECTIOUS ABORTION.

Some experimental and very practical work has been done with infectious abortion in the dairy herd. Among other points which have been demonstrated in this work it has been shown that cattle are able to take very large doses of carbolic acid—many times larger doses than was previously supposed possible. In a general way the endeavor in this work has been to free the University Dairy Herd entirely from the infection before the cattle were moved to the new barn. A very large amount of disinfection work was done with both the male and female cattle in addition to internal administration of carbolic acid in large doses. Careful records have been kept. During the present season there have been very few abortions and there is some uncertainty as to whether these were of infectious type.

NORTHEAST EXPERIMENT FARM.

Eighty acres of the one hundred twenty-six acres under cultivation are given to a practical demonstration of a system of farming considered best for this section of the state.

The crops grown are as follows: Oats, 20 acres; clover and timothy hay, 20 acres; fodder corn, 14 acres; barley, 6 acres; wheat, 4 acres; potatoes, 4 acres; peas, 2 acres; stock roots, 2 acres; tame grass for night pasture, 6 acres.

With these crops, six series of rotation are carried on:

1. Wheat, clover and timothy, fodder corn, potatoes. Ground manured lightly for fodder corn and the following year for potatoes, 4-year rotation, four fields;

2. Oats, barley, clover and timothy, fodder corn. 4-year rotation, four fields;

3. Oats two years, clover and timothy two years. 4-year rotation, two fields;

4. Fodder corn, oats, clover and timothy pasture two years. 4-year rotation, two fields;

5. Fodder corn, oats, clover and timothy hay. 3-year rotation, three fields. Ground manured for fodder corn;

6. Stock roots, barley, clover, peas. 4-year rotation, four fields.

With the exception of potatoes, all the crops grown are fed on the farm and the products sold in the form of butter, meat and eggs.

Twenty-two cows were milked during the past year. Their butter production is not yet computed to date, but will average better than two hundred and fifty pounds per cow. Of the twenty-two cows only six are pure bred (Guernseys, bought September, 1907). Common grade cows of the dairy type have been kept to show what profit can be made in dairying with such cows as the farmer has in his possession. A pure bred Guernsey bull is being used for building up the future herd.

In hogs, the large improved Yorkshires are being raised. They are grown mostly on skim milk and clover pasture and those not sold for breeding stock, fattened on barley and peas. The bacon hog is recommended for this section of the state to be raised in connection with dairying. Dairying and bacon hog raising are

recommended as the principal branches of agriculture for Northeastern Minnesota.

In our winter dairying, the cows are fed on clover and timothy hay, fodder corn, fodder corn ensilage, stock roots, bran, and shorts. The butter is made on the farm and sold on the local market. The price for the past year averaged 28 cents per pound.

During the year, the dairy barn was enlarged and remodeled and a root cellar of 3,000 bushels capacity built in connection with it. The barn is now 110 feet long by 32 feet wide and will accommodate forty head of dairy cows and a corresponding number of young stock.

A new hog barn 20x42, a granary 24x26, and a concrete well house were built.

The yield of the crops grown under field conditions is as follows: Oats, 35.5 bushels per acre; wheat, 17 bushels; barley, 22.7 bushels; peas, 8 bushels (badly drowned out); clover and timothy hay, 3 tons, single cutting; fodder corn, green, 11.5 tons; field cured, 6 tons; stock roots, 10 tons; potatoes, 184 bushels. The fore part of the growing season was very wet.

Varieties grown: oats, Improved Ligowa; wheat, Minnesota No. 169; barley, Mandschuria; peas, Canada field; roots, Mastodon stock carrot; potatoes, Carmen No. 1; hay, medium red clover and timothy, alsike clover on low land.

Different varieties of the various grains, etc., were grown on small test plots, but none have proved better adapted to the country than the varieties grown on the fields, which are the result of several years of selection.

Various experiments in different methods of tillage and rotation were conducted on small plots—thirty-two tenth-acre plots being used for this purpose. The results obtained on the small plots, which have been in operation for a number of years, confirm the system of cropping on the large fields that is being made demonstrative of the right system of farming for this section of the state.

The growing of vegetables and small fruits has been done with the usual success. Apples thus far have not proved a success, winter-killing badly. The strawberry, raspberry and currant have proved most profitable.

The open winter made easy the gathering up of considerable down wood. About four hundred cords of wood were removed,

aiding greatly in clearing the land for pasture. Twenty thousand feet of logs were also gotten out and sawed into rough lumber.

The uncleared part of the farm that is not being kept for growing timber, is being cleared up as fast as the means will permit.

The results of the farm work are published in press bulletin form and copied in nearly one hundred papers in this northeastern section of the state. In this way, the farmers become acquainted with the work of the farm and the results obtained.

During the months of November and December, the Superintendent conducts meetings in the northeastern section of the state under the supervision of the Farmers' Institute, and in this way the work is brought still further before the farmers. At any time during the year, when the farmers are in need of a meeting for the purpose of an organization, the Superintendent personally assists them. Numerous organizations have been formed with a view of securing better and more uniform seed, better breeding stock, and for the development of the dairy industry through the co-operative creamery. The agricultural outlook for this section of Minnesota is encouraging.

NORTHWEST EXPERIMENT FARM.

The chief work of the Northwest Experiment Farm the past year has been the installation of an experimental drainage system, the full account of which is given in Bulletin No. 110, soon to be issued. The season of 1908 has been one of the driest on record so that the ditches and tile were in operation for only a few weeks in the spring. The working of the system will be reported later.

About fifty acres of timothy and clover are seeded each year. Both do well here and there is no reason why farmers should hesitate to sow them more extensively.

Of the five varieties of wheat—two macaronies and University 169 (a blue stem), 188, and 163—169 yielded much the best.

A small patch of alfalfa planted several years ago continues to thrive well, no winter-killing being noticeable. Five varieties were seeded this year for trial all of which have made a promising catch.

Three varieties of Canadian field peas are being tested the present season. It is too early to report results.

In stock at the Northwest Experiment Farm, no attempt is made to keep a representation of a large number of breeds. The

present policy is rather to represent types, and to do this by breeds seemingly best adapted to the locality. So in poultry the farm keeps only Barred Rocks and Single Comb White Leghorns; in swine, Yorkshires and Duroc Jerseys; in cattle, the Shorthorns and Holsteins; and in sheep, the Shropshire grades. A few Galloway cattle are still on hand, but will be closed out the coming winter.

The poultry plant continues to thrive. About 2,000 chicks were hatched out the present season. The gross receipts from the plant the past fiscal year, aside from that used at the farm house, amounted to about $1,000. Returns from the cattle amounted to about $1,350.

The flock of sheep is as yet rather small, numbering slightly over fifty. The clip for the season of 1908 averaged 9.6 lbs. per individual. The plan is to increase the flock gradually to about 150. Sheep seem to be well adapted to the region of the Red River Valley, and require little attention except at lambing time.

BULLETINS PUBLISHED.

The station has published during the year four press bulletins and eight general bulletins, a list of which is given on another page. The call from farmers for these publications is increasing yearly so that it has become necessary to enlarge the edition. In accordance with law bulletins are sent only to those interested in agriculture and who make application for them. The mailing list is constantly revised and is a means for distributing information resulting from the research work of the station.

Respectfully submitted,

E. W. RANDALL,
Director.

Reprint of Bulletin No. 102 of this Station.

FERTILIZER TESTS WITH WHEAT AND CORN.

HARRY SNYDER.

Introduction.—In 1905 experiments were undertaken in various parts of the state to determine the influence of fertilizers upon the yield and composition of wheat and corn. The results are published in bulletin No. 94. The next year it was deemed advisable to repeat the experiments so as to secure results for more than one season, and also to extend them to soil areas not included in the former tests. This bulletin gives the results of the experiments of 1906.

At the present time but little commercial fertilizer is used in general farming in this state. Many questions are asked, however, in regard to the use of fertilizers on Minnesota soils and these tests have been carried on with the view of securing information upon this subject.

In this work valuable assistance has been rendered by graduates, former students of the School of Agriculture and others, who made the coöperative tests upon their farms, and reported the results. The general plan and the object of the experiments are set forth in the following directions furnished to those engaged in making the tests.

Directions for Making Fertilizer Tests with Wheat.

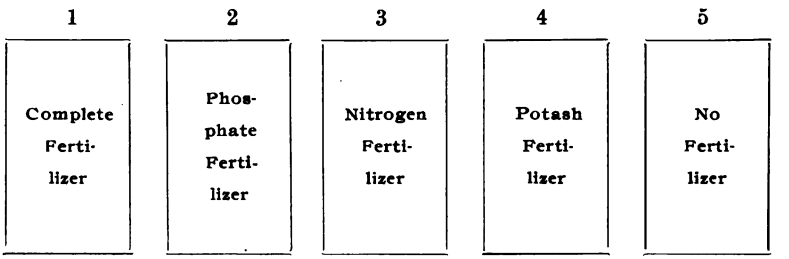
Selection of Land.—Select a uniform piece of land so that five quarter acre plots similar in character can be staked off. It is essential that the several plots be as similar as possible. Select the oldest soil available. One of the objects of the test is to determine the effects of the fertilizers upon the yield and quality of wheat grown on old soils. The several plots should be equally well drained. They should all be plowed alike and given the same treatment as to harrowing and rate of seeding.

Staking off the Plots.—Plots 10 rods long and 4 rods wide will be found a convenient form for working. In laying off the plots, see that no dead furrows make the plots uneven. Between adjoining plots, a division space

MAP OF MINNESOTA

Showing location of places where fertilizer tests were made in 1906.

of three feet should be left. The plots can be staked off in the way suggested in the diagram. Plot labels for the stakes and line for measuring off the plots are sent with the fertilizers.



Applying the Fertilizer.—On Plot No. 1, 150 lbs. of complete fertilizer are to be applied. This is guaranteed to contain 10 per cent of available phosphoric acid, 5 per cent of potash, and 5 per cent of ammonia, and costs $28.00 per ton. On the quarter acre $2.10 worth of fertilizer is to be used. This fertilizer can be applied broadcast, or put into the drill either just before or just after seeding, preferably before seeding. Some fertilizers feed well from the drill boxes, and others not so well. If sown by hand, it should be done when there is no wind. The main thing is to apply the fertilizer as evenly as possible. The land is to be seeded in the usual way, and in seeding, the plots can all be treated as one large field, or as a part of a field.

On Plot No. 2, 80 pounds of dissolved phosphate rock fertilizer are to be applied. This fertilizer contains 14 per cent of available phosphoric acid and costs $16.00 per ton, or $2.56 per acre.

On Plot No. 3, 40 pounds of nitrate of soda, containing 16 per cent nitrogen are to be applied. This fertilizer costs $60.00 per ton, making it $3.60 per acre.

On Plot No. 4, 40 pounds of muriate of potash, 80 per cent, costing $50.00 per ton, or $4.00 per acre, are to be applied.

The general plan of the experiment is to apply each of the plant food elements, phosphorus, potassium and nitrogen, separately and also in combination so as to determine the effects which they have upon the yield and quality of the grain.

It is to be noted that on Plot No. 5 no fertilizer is to be used. This is the check plot and the yields are to be

used for comparison with the yields from the other plots. In a number of last year's tests, clover was seeded with the wheat, and it was found that the phosphate and potash fertilizers were specially beneficial in encouraging a good stand of clover. The extra expense involved in threshing separately the wheat from these fertilizer plots will be paid by the Station. In all probability the increased yield will more than pay for the labor involved. The figures given for the cost of the fertilizers are prices F. O. B. Minn. Transfer, 1907. In 1906 the complete fertilizer cost $2.00 more and the phosphate $1.00 less per ton.

The fertilizers used were purchased in the open market and were found upon analysis to have the following composition:

	Total Nitrogen.	Phosphoric acid.	Potash.
	Per cent	Per cent	Per cent
Complete fertilizer	3.65	12.14	5.22
Nitrate of Soda	15.61		
Muriate of Potash			55.00
Acid Phosphate		17.25	

Experiments at University Farm, in co-operation with the Agricultural Division.

Mr. Bassett, Farm Superintendent, reported Oct. 4, 1906: "The plots where this wheat was grown are very uniform in character of soil, fertility and previous cropping. The wheat used in this experiment is Minnesota No. 188. This wheat has a ten year average with us of 28.97 bushels." The yields were as follows:

Plot No.	Plot Size	Date sown	Amount seed sown	Kind of fertilizer used	Amount used. Per plot lbs.	Amount used. Per acre lbs.	Time applied	Yield per plot. Straw lbs.	Yield per plot. Grain lbs.	Yield per acre. Straw Tons	Yield per acre. Grain Bu.
1	¼	4/21	1¼	None	0	0	5/3	612	393	1.22	26.2
2	¼	4/21	1¼	Nitrogen	40	160	5/3	680	415	1.36	27.6
3	¼	4/21	1¼	Potash	40	160	5/3	599	426	1.19	28.4
4	¼	4/21	1¼	Phosphate	80	320	5/3	529	391	1.05	26.
5	¼	4/21	1¼	Complete	150	600	5/3	754	456	1.5	30.4

The following notes as to the appearance of the crop were taken just prior to harvest:

Plot I. No fertilizer, good heads fairly well filled, good straw, mature.

Plot II. Nitrogen fertilizer, good large heads well filled, but apparently weak in straw as it had a tendency to lodge. Not mature, about two days later than the other plots.

Plot III. Potash fertilizer, good, large, well filled heads, mature. The straw was strong and bright.

Plot IV. Phosphate fertilizer, good, large well filled heads, mature. The straw was nearly as strong and bright as on plot III.

Plot V. Complete fertilizer, good large heads, more grain than on the other heads, matured two days later. Straw weak, lodged, larger growth than the others.

In these experiments the increased yield obtained from the use of nitrogen, phosphorus and potassium fertilizers alone or in combination was not sufficient to pay for the fertilizer. Somewhat similar results were secured from the tests made in 1905. As those of 1906 were on a different part of the farm from those of 1905 the results of the two years are not comparable in all respects. The experiments show that when soil is in a high state of fertility, commercial fertilizers can not be economically used.

Experiments at Langdon, Washington County, by Geo. Hummel.

Kind of Fertilizer.	¼ acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	226	15
Nitrogen	246	16½
Phosphate	286	19
Potash	298	20
Complete	266	17¾

Mr. Hummel reported: "The complete was about five days earlier than the others and seemed to look better, but just before time for cutting, it lodged badly. The phosphate also ripened earlier and stood up well."

The potash fertilizer produced an increase in yield at the rate of five bushels per acre and at a cost of $4.00 and the phosphate fertilizer an increase of four bushels, at a cost of $2.56. The low yield obtained from the complete fertilizer was probably due to inability to completely harvest the lodged wheat.

Experiments with wheat at Waltham, Mower Co., by J. F. Ziemer.

KIND OF FERTILIZER.	¼ acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	187	12⅓
Nitrogen	181	12
Phosphate	256	17
Potash	305	20⅓
Complete	326	21⅔

Mr. Ziemer writes: "Land was of uniform character. It had been in clover and timothy two years, and produced a crop of oats in 1905. Wheat seeded April 21st and harvested on August 9th. Season was wet and red rust damaged wheat in this vicinity. The grain on the plot receiving the complete fertilizer and that receiving the phosphate was far ahead of the plot receiving the nitrogen and the check plot, all through the growing season. The grain on these last two plots was badly rusted. The grain on the potash plot was not rusted much; the straw was not so long, but was greener early in the season and brighter at time of harvest than that on any of the other plots. The grain on the complete and phosphate plots matured several days ahead of the others. The potash plot produced the stronger straw and best quality of grain. All of the plots were seeded to clover and timothy. The clover looks best on the phosphate plot."

The application of muriate of potash at the rate of 160 pounds per acre and costing $4.00 gave an increase of eight bushels per acre of wheat worth about $7.20. Nitrogen alone gave no increase in yield, probably due to the land having been in clover only two years prior to the experiments. From the use of 340 pounds per acre of phosphate fertilizer, costing $2.56, an increase of 4⅔ bushels of wheat was secured worth about $4.20.

Experiments at St. James, Watonwan Co., by Otto Uhlhorn.

KIND OF FERTILIZER.	¼ acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	257	17
Nitrogen	230	15⅓
Phosphate	339	22⅔
Potash	294	19½
Complete	344	23

Mr. Uhlhorn writes: "Complete,—a little rank but healthy in appearance.

Phosphate,—healthy in appearance.

Potash,—very rigid, bright, healthy appearance.

Nitrogen,—weak, dirty looking, sickly.

No fertilizer,—stiffness fair, appearance not as healthy as first three.

The land had been in corn in 1905. The wheat was seeded April 19th, and fertilizer applied broadcast. Complete, phosphate and potash plots were harvested August 6th. Nitrogen and no fertilizer plots were harvested August 10th."

The potash gave an increase of about two bushels per acre, and the phosphate 5½ bushels. The cost of the phosphate fertilizer was more than repaid by the gain in wheat. All of the other fertilizers were used at a financial loss.

Experiments at Starbuck, Pope Co., by H. M. Johnshoy.

Kind of Fertilizer.	¼ acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	113	7½
Nitrogen	123	8
Phosphate	208	14
Potash	166	11
Complete	249	16½

Mr. Johnshoy reports: "The grain on the complete fertilizer plot lodged badly. The phosphate gave the best grade of grain, according to my judgment." The largest increase at the least expense was secured from the use of the phosphate fertilizer. The application of phosphate fertilizer at the rate of 320 pounds per acre and costing $2.56 gave an increase of 6½ bushels of wheat per acre.

Experiments at Benson, Swift County.

In 1905 quarter acre plot tests were made with fertilizers upon wheat, at the farm of W. M. Liggett, under the supervision of Alex Boss. The soil used was old clover land. When the potash and phosphate fertilizers were used alone, each showed an increase in yield of four bushels per acre and when used jointly in a complete fer-

tilizer with nitrogen, an increase of eight bushels per acre was secured. When nitrogen alone was used there was no increase in yield.

It was deemed best to repeat the experiments in 1906, and also to increase the number and size of the plots. The field used in 1906 was in a lower state of fertility than that of 1905, which was old clover soil. In the experiments of 1906 particular attention was given to the potash and phosphate plots. Dissolved bone was applied to one of the plots so as not to introduce an unknown factor, as gypsum in the acid fertilizer, which is capable of liberating potash through indirect action upon the soil. The yields from the various plots are given in the following table:

Trial on large plots. Wheat.

KIND OF FERTILIZER.	Amount used lbs.	Size of plot acres.	Bu. wheat per acre.
Potash (muriate)	300	5	18
Phosphate (dissolved bone)	500	5	15
Potash	200		
And dissolved bone	400	4	15¼
No fertilizer		1	12
Acid Phosphate		1	15
Potash	60		
And acid phosphate	200	1	15
Acid phosphate	200		
Potash	60		
Nitrate of soda	75	1	21

Trial on small plots. Wheat.

KIND OF FERTILIZER.	¼ acre plots lbs. wheat.	Yield 1906 Bu. per acre.	Yield 1905 Bu. per acre.
No fertilizer	180	12	16
Nitrogen	240	16	16
Phosphate	210	14	20
Potash	180	12	20
Complete	300	20	24

"The potash plot was a few days ahead of the others in ripening, but there was not much difference in plumpness of grain or stiffness of straw. Of the larger plots, the potash plot (No. 1) was apparently the best, being very rank. However, the plot was a little lower than the others. The one acre unfertilized plot showed a falling off both in stand of straw, length of straw and heads. The wheat on this plot lodged quite badly." The

plots were reasonably level. The land had been cropped about 25 years, and but little manure had been used. Oats and corn had been the preceding crops.

It is to be noted that while the plot yields of 1905 indicated that potassium and phosphorus were the elements of plant food most needed, the trials of 1906 on land where clover had not been grown, showed an increase of six bushels of wheat per acre from the addition of 75 pounds of nitrate of soda with the potash and phosphate fertilizers. Muriate of potash gave the best results of any of the fertilizers used alone, but not as large a yield by three bushels per acre as when combined with phosphates and nitrogen. From a financial point of view, the 200 lbs. of acid phosphate, 60 lbs. of muriate of potash, and 75 lbs. of nitrate of soda formed the best fertilizer, costing $4.68 per acre, and giving an increase in yield of nine bushels of wheat per acre.

Experiments at Montevideo, Chippewa Co., by O. M. Olson.

KIND OF FERTILIZER.	¼ acre plots lbs. wheat	Bu. of wheat per acre.	
		1906	1905
No fertilizer	240	16	20
Nitrogen	300	20	20
Phosphate	330	22	24
Potash	240	16	20
Complete	330	22	25

In his report Mr. Olson states: "As in the previous year, the various fertilizers were used upon wheat, and sown upon land old in cultivation and several years since any manure was applied. The plots were 20 feet wide and estimated to be 33 rods long, lying across the dead-furrows and back-furrows, giving more accuracy in the results. The grain was sown with a drill on well prepared soil on April 18th, and the fertilizers were sown broadcast by hand and harrowed in on April 19th. There was nothing noteworthy about the plots until the middle of July when the phosphate, potash and complete fertilizer plots headed out about the same time and about ten days prior to the balance. On Aug. 1st, Prof. Hummel and I carefully inspected the plots, making notes on height, general crop condition and other noticeable features. Notes on height

Complete fertilizer. No fertilizer.

Fig. 1.—Fertilizer plots, farm of O. M. Olson.

and condition were taken at three different parts of the field. The average height of the grain was found to be as follows: no fertilizer, 40+; phosphate, 42; potash, 41+; nitrogen, 41+; complete, 48—.

"The grain was shock-threshed September 2nd and the yield determined by an automatic weigher. It may be well to add that corn followed the grain crop on which the fertilizers were sown the previous year and there was a noticeable difference in the corn crop, but as the lines of the plots were lost no definite information can be given."

In the 1906 tests, the potash fertilizer used at the rate of $4.00 worth per acre gave an increase of six bushels per acre of wheat, and the $2.56 worth of phosphate fertilizer caused an increase of four bushels per acre. The potash used alone gave as good results as the complete fertilizer.

Experiments at Renville, Renville Co., by N. J. Holmberg.

Kind of Fertilizer.	¼ acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	180	12
Nitrogen	180	12
Phosphate	240	16
Potash	210	14
Complete	210	14

Notes.—"Conditions this year were very unfavorable for making a good test. Wheat in this locality under the most careful preparation of the soil, was not up to the mark. We had a severe wind and rain storm shortly before harvest, that broke down considerable of the straw. The wheat on the phosphate plot appeared better and stronger from start to finish; it grew about four inches taller than the rest of the wheat. The quality of the wheat was poor on all of the plots.

Fig 2.—Fertilizer plots, farm of N. J. Holmberg. N. Nitrogen fertilizer. K. Potash fertilizer. P. Phosphate fertilizer. Com. Complete fertilizer. Check, No fertilizer.

"As near as I have been able to observe I do not think that it would pay to use these fertilizers to any large extent; the labor of applying is quite an item. What we need here is barnyard manure and rotation of crops." During growth the plots ranked as follows: 1, phosphate; 2, potash; 3, complete. It is to be noted that the increased yield of four bushels per acre from the use of the phosphate fertilizer just about paid for the fertilizer, not counting the labor involved.

Experiments at Litchfield, Meeker Co., by N. O. Evenson.

Mr. Evenson reports: "I did not keep the different plots separate as there was very little if any difference between them, and besides all early seeded grain was very badly lodged in this section this year. We stacked the grain separately, from the four plots that had received fertilizers, to see in a general way if there was any difference in the quality, but could not see any."

Experiments at Lynd, Lyon Co., by Sup't. O. C. Gregg.

OATS.

KIND OF FERTILIZER.	¼ acre plots lbs. straw.	¼ acre plots lbs. oats.	Bu. oats per acre. 1906.	1905.
No fertilizer	735	490	61	74
Nitrogen	835	545	68	70
Phosphate	885	525	65½	66¼
Potash	840	540	67½	67½
Complete	960	485	60½	88¼
Barnyard manure	663	407	51	76

WHEAT.

No. of plot	KIND OF FERTILIZER.	Amount used, lbs.	Size of plot, acres	Lbs. straw per plot.	Lbs. grain per plot.	Bu. wheat per acre.
1	Complete	500	2	5331	1820	15
2	Muriate potash	150	2	5374	2310	19¼
2	Phosphate	300				
3	Muriate potash	150	2	5040	2105	17½
4	Phosphate	210	2	4956	1690	14
5	Muriate potash	150	2	5582	2270	19
6	No fertilizer		2	4100	1715	14¼
7	Muriate potash	100	1			
7	Nitrate soda	75	1	2760	1085	18
8	Phosphate	150	1			
8	Nitrate soda	75	1	2839	935	15½

Notes, Oat plots. Coteau farm experiments. "The plot to which barnyard manure was applied was next to a willow hedge, and also had one low spot in it so the yield cannot be taken as giving anything definite."

"Wheat plots; remarks concerning condition of straw:

Plot 1. Complete fertilizer. Good stand. Straw very tall and straight. Well headed.

Plot 2. Potash and phosphate fertilizer. Quite green at time of harvesting. Straw short, weak, tangled. Well headed.

Plot 3. Potash. Straw stood upright. Stand even. Well headed. Straw bright.

Plot 4. Phosphate. Badly down. Tangled most of any. Straw appeared decayed. Heads were short. Started to head earliest. Ripest plot at time of cutting.

Plot 5. Potash. Stand not heavy, rather thin. Straw about six inches shorter than the rest. Heads short. Straw crinkled.

Plot 6. No fertilizer. Straw straight and bright. Stand even and quite heavy. Well headed. Mediumly ripe.

Plot 7. Nitrogen and Potash. Straw bright and straight.

Plot 8. Nitrogen and phosphate. Stand appeared good. Straw bright and straight. Heads short. Stand was a little better than No. 7."

In these experiments with oats, no material increase in yield was secured from the use of any of the fertilizers. In the experiments with wheat, neither nitrogen nor phosphorus when used alone or in combination caused any noticeable increase in yield, but the potash fertilizer applied at the rate of 75 pounds per acre gave an average increase of three bushels of wheat. This increase was secured from the use of about $1.88 worth of fertilizer. In the 1905 experiments on this land phosphates applied to wheat gave no increase in yield.

Experiments at Pipestone, Pipestone Co., by Robert Dailey.

Mr. Dailey reports: "There was a larger growth of straw on all of the fertilized plots, except the phosphate, than on the check plot and the grain matured from three days to a week earlier on these plots. Clover on the potash

and phosphate plots was much more rank than on the others."

No material increase in yield from the use of the fertilizers was noted on any of the plots, the largest increase being 1¼ bushels per acre for the potash plot. All of the fertilizers were used at a financial loss.

Experiments at the Grand Rapids substation, by Sup't. A. J. McGuire.

Kind of Fertilizer.	¼ acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	325	21¼
Nitrogen	279	18½
Phosphate	281	18¾
Potash	333	22¼
Complete	326	21¾

Mr. McGuire states that the "first part of the season was quite wet. Later it was dry from two weeks before heading out till ripe, thus maturity was hastened. The grain on the fertilized plots headed out three or four days earlier than on the unfertilized plot. The grain on the potash plot matured about three days earlier than on any of the others. Also the straw was stiffer, and a little larger, and the grain of a little better quality. On the complete fertilizer plot the straw was ranker and lodged some."

No material increase in yield was secured from any of the fertilizers.

Experiments at Park Rapids, Hubbard Co., by Dr. P. D. Winship.

Kind of Fertilizer.	1/5 acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	108	9
Nitrogen	200	16⅔
Steamed bone meal	140	11⅔
Potash	110	9⅙
Brown rock phosphate	216	18
Tenn. rock phosphate	110	9⅙

"The experiments were made on old land wheated 23 years. Black rust affected the wheat."

Dr. Winship also states: "About the time the wheat should have ripened we had a very hot dry spell which seriously injured the crop. I found that all fertilized wheat stood up better and made a decidedly better grade

of wheat. No unfertilized wheat stood up and only the fertilized wheat made any grade at all. While the tests were unsatisfactory they show that all the fertilizers used were of decided benefit to the crop and land. I made a test on a larger scale with ground Tennessee rock phosphate, plot 20 acres. I sowed one half with rock phosphate and left one half unfertilized with the following results: The ten acres phosphated yielded white oats, machine measure, 420 bushels, weighed out at elevator, 519 bushels; unphosphated 10 acres, machine measure, 220 bushels, weighed out at elevator 240 bushels; leaving me a net gain for phosphate, 279 bushels at 26 cents per bushel, $72.54. Cost of fertilizer laid down on farm, $11.50 per ton. 500 pounds per acre were used, costing $2.87½ per acre, leaving a net profit for rock phosphate of $4.38 per acre. The effect of rock phosphate on clover is marked. While we have had one of the best clover years ever known, the phosphated land showed 100 per cent better than unphosphated land. The catch is better, the growth is better and the bacterial tubercles are larger and stronger."

Experiments at Randall, Morrison Co., by Geo. W. Danielson.

Mr. Danielson reports that "there was not difference enough to pay to harvest and thresh separately. I had the plots cut as one field. The complete and the nitrogen fertilized plots however, looked the best. The potash was much thinner on the ground and ripened a few days earlier than the rest of the plots."

The yield was not very good. We threshed from the experiment plots 17½ bushels of Minnesota No. 169 wheat, being about two bushels per acre more than the average yield for the unfertilized wheat.

Experiments at Vining, Ottertail Co., by M. B. Lund.

Kind of Fertilizer.	¼ acre plot lbs. wheat.	Bu. wheat per acre.
Phosphate	180	12
Potash	240	16

Mr. Lund reports: "A heavy rain laid everything in the line of small grain flat to the ground, except

the potash plot which stood up like brush, and the phosphorus plot which stood up fairly well. Three of the plots are not reported because the grain was badly lodged."

Experiments at Ulen, Clay Co., by L. A. Larson.

These experiments were made on land that had been under cultivation for a number of years. At the time of harvest there was no appreciable difference between the wheats grown upon the plots fertilized with the commercial fertilizers and the unfertilized plot. There was not sufficient difference to warrant separate cutting and harvesting of the grain. The experiments indicate as do similar experiments in the Red River Valley, that the lessened yields of wheat during the past few years have not been due so much to soil exhaustion as to unfavorable climatic conditions, and lack of proper drainage.

Experiments at Warren, Minn., by James Frank.

September 12, 1906, Mr. Frank reports: "I have just finished cutting and threshing the grain on my farm and find that the only increase in yield from the four experimental plots was from the complete fertilizer plot. This complete fertilizer plot yielded about one half bushel more than the other plots. The fertilizers were applied about ten days after the wheat was sown. The nitrogen and potash were sown broadcast on account of being too coarse to go through the grain drill, while the phosphate and complete fertilizers were drilled in. On account of the wet weather this past season the yield was light, the average being about 14 bushels."

It is to be noted that in this case all of the fertilizers were applied at a financial loss.

Experiments at Ada, Norman Co., by A. K. Strand.

These experiments were made on heavy black loam, overlying a marl subsoil, containing numerous shells. No manure had ever been applied, and the land had been under nearly continuous wheat cultivation. The excessive wet weather and unfavorable climatic conditions reduced the yield from all of the plots. The nitrogen, potash and phosphate fertilizers did not cause any material increase in yield—only from one to one and a half bushels per acre. The complete fertilizer applied at the rate of 600 pounds

per acre and costing $8.40 gave an increase of five bushels of wheat worth about half the cost of the fertilizer.

Experiments at Breckenridge, Wilkin Co., by C. M. Beeson.

Kind of Fertilizer.	¼ acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	83	5½
Nitrogen	76	5
Phosphate	132	8¾
Potash	114	7½
Complete	154	10¼

Mr. Beeson reports: "The land has never had an application of fertilizer of any kind and intentionally very poor land was selected. The wet weather this year (1906) has made the yield very low. From the first, the complete and phosphate fertilizer plots looked healthier and stronger, and the grain was ripe fully five days before the other three plots. The straw on the complete fertilizer plot was more rank than that on the phosphate plot, and both were noticeably taller than the rest of the plots. As to the quality of the grain there was a little difference in favor of the phosphate."

During former years, when the rainfall has not been excessive, 20 to 30 bushels per acre of spring wheat have been secured in this county. The low yields reported are due to unfavorable climatic conditions rather than to lack of fertility. It is to be noted that even during unfavorable years an addition of plant food to the soil favorably affected the yield.

Experiments at Brown's Valley, Traverse Co., by Hon. J. T. Schain.

Kind of Fertilizer.	¼ acre plots lbs. wheat.	Bu. wheat per acre.
No fertilizer	171	12
Nitrogen	240	16
Phosphate	284	19
Potash	259	18
Complete	299	20

Clover was seeded with the wheat and Mr. Schain reports: "The clover looked the best on the plots that received the nitrogen and next best on the potash

plot." As the result of one season's tests the complete fertilizer applied at the rate of $8.10 worth per acre gave an increase of eight bushels of wheat, about sufficient to pay for the fertilizer used. An increase of seven bushels per acre was secured from the use of the $2.56 worth of acid phosphate fertilizer. The potash alone gave an increase of six bushels per acre at a cost of $3.60. Both potash and phosphate fertilizers were profitably used on this land for the production of wheat.

Experiments at Dover, Olmsted Co., by Forest Henry.

Mr. Henry reports: "We sowed and harrowed in the several fertilizers as directed, after the barley had been put in with a drill. Very little difference could be detected during the early part of the season, save that the plot that received the nitrogen fertilizer took on a darker green color and stood ranker. As harvest time approached all the plots that received the fertilizer save the one above mentioned seemed to come on faster and were several days in advance of the remainder of the field. There was no appreciable difference in the quantity or quality of the grain at harvest time. It all stood very heavy. Much of it was lodged and tangled by a heavy storm. It was so badly lodged at harvest time that I could not give each plot a fair chance and so threshed all together. The whole field made 50 bushels to the acre. I think it would have been better had we used the fertilizer on thinner land."

Experiments with fertilizers on onions at Pine Island, Goodhue Co., by Lloyd Bush.

"The fertilizers were applied to small plots, 1/70 of an acre, the yields secured were reported as follows:

Kind of Fertilizer.	Lbs. onions per plot.
Nitrate of soda alone	266
Acid phosphate	254
Muriate of potash	252
Nitrate and acid phosphate together	279
Nitrate and muriate of potash together	264
Acid phosphate and muriate of potash together	249
All three together	316
No fertilizer	243

There was a gain of 73 pounds from the use of all three fertilizers over using none at all."

Experiments at New Ulm, Brown Co., by Herman Pfaender.

Mr. Pfaender reported that the corn on the experi-

mental plots was harvested by stray cattle. During growth a difference between the fertilized and unfertilized plots was noticeable, "particularly so in the case of the complete and potash plots. My other corn, however, which received a good coating of manure yielded 80 bushels per acre. From my observations last season and this, I have come to the conclusion that commercial fertilizers are not needed for general farming. I say keep plenty of stock and haul the manure right from the barn onto the field. Our Minnesota farms are not yet so impoverished that they cannot be reclaimed by a judicious application of farm manure."

Experiments at Northfield, Rice Co., by Matthew Frame.

Kind of Fertilizer.	⅛ acre plots lbs. corn.	Bu. corn per acre.
No fertilizer	486	55½
Nitrogen	445.5	51
Phosphate	544.5	62½
Potash	513	58½
Complete	450	51½

Mr. Frame states: "The complete fertilizer gave an abundance of fodder and although the ears were quite large they did not weigh well. The nitrate of soda seemed to be an injury rather than a help; the ears were small and shrivelled, with stalks nearly all on the ground. The phosphate and potash plots produced better and more mature ears than either of the other plots."

Experiments at Zumbro Falls, Wabasha Co., by David Boss.

Kind of Fertilizer.	⅛ acre plots lbs. corn.	Bu. corn per acre.
No fertilizer	754	86
Nitrogen	693	79
Phosphate	723	82½
Potash	722	82½
Complete	721	82½

Mr. Boss reports: "The unfertilized plot was somewhat lower ground, and the soil was perhaps richer. The corn was yellow dent and was a fine crop."

Experiments at Elk River, Sherburne Co., by S. R. Houlton.

KIND OF FERTILIZER.	⅛ acre plots baskets corn.	Baskets corn per acre.
No fertilizer	6½	52
Nitrogen	8	64
Phosphate	7½	60
Potash	7	56
Complete	7¾	62
Farm manure, 15 loads per acre	9½	76

Mr. Houlton states: "We selected a badly run down piece of light sandy soil for the trials. On land properly kept up and naturally more fertile we husked as high as 140 baskets per acre, this being an unusually favorable season here for corn."

Experiments at Amboy, Blue Earth Co., by H. A. Ludtke.

KIND OF FERTILIZER.	⅛ acre plots lbs. corn.	Bu. corn per acre.
No fertilizer	437	50
Nitrogen	456	52
Phosphate	516	59
Potash	515	59
Complete	464	53

Experiments at Fairmont, Martin Co., by L. A. Sweet.

KIND OF FERTILIZER.	⅛ acre plots lbs. corn.	Bu. corn per acre.
No fertilizer	362	41½
Nitrogen	346	39½
Phosphate	419	48
Potash	415	47½
Complete	462	52¾

Mr. Sweet reports: "The ground was high and quite level. It was fall plowed and the corn was planted May 12th. The fertilizer was sown broadcast. The land has never raised a crop of clover and has had no manure for five or six years. The corn was given a fair amount of cultivation and was quite free from weeds."

Experiments at Brownsdale, Mower Co., by F. O. Tanner.

Kind of Fertilizer.	⅛ acre plots lbs. corn.	Bu. corn per acre.
No fertilizer	310	35½
Nitrogen	329	37½
Phosphate	394	45
Potash	324	37
Complete	360	41

Experiments at Austin, Mower Co., by J. E. Galloway.

Kind of Fertilizer.	⅛ acre plots lbs. corn.	Bu. corn per acre.
No fertilizer	454	52
Nitrogen	443	50½
Phosphate	464	53
Potash	512	58½
Complete	566	64½

Mr. Galloway reports: "On the complete and potash plots the stalks were better and stood up well. On the other plots the stalks were weaker and more or less broken down."

Experiments at Hagen, Chippewa Co., by Edward Hagen.

Kind of Fertilizer.	⅛ acre plots lbs. corn.	Bu. corn per acre.
No fertilizer	582	66½
Nitrogen	595	68
Phosphate	585	67
Potash	563	64½
Complete	579	66

Mr. Hagen states: "The plot receiving the potash fertilizer had an old dead furrow running through it and that I think accounts for the light yield."

Experiments at Hanley Falls, Yellow Medicine Co., by Ernest P. Squire.

KIND OF FERTILIZER.	⅛ acre plots baskets corn.	Baskets corn per acre.
No fertilizer	14¼	114
Nitrogen	14¾	118
Phosphate	15½	124
Potash	15	120
Complete	16½	132

Mr. Squire writes: "When the corn was a few feet high one could easily see where the fertilizers had been applied by the more luxuriant growth. When I husked the corn from the complete fertilizer plot, I noticed the difference immediately by the extra large, heavy, well filled ears."

SUMMARY.

Nineteen series of experiments with fertilizers on wheat were made in different parts of the state. In eleven of these an increase of from 2½ to 9 bushels per acre was secured from the use of 320 pounds per acre of an acid phosphate fertilizer, costing $2.56. An increase in yield of at least three to four bushels per acre is necessary to pay for the fertilizer; in eight of the tests such an increase was secured. In ten of the serial tests muriate of potash gave an increase. The potash fertilizer was applied at the rate of 160 pounds per acre and cost $4.00, exclusive of labor. An increase of five to six bushels of wheat is required to pay for the fertilizer. In four of the serial tests the increase in yield from the use of the potash was five bushels or more. Nitrogen, as nitrate of soda, when used alone gave no noticeable increase except in two cases. The complete fertilizer applied at the rate of 600 pounds per acre, gave an increase of two to nine bushels in eleven of the trials. In no case was the increase sufficient to pay the cost of the fertilizer, $8.40. In six of the eleven tests approximately this same increase was secured from the phosphates used alone and costing $2.56 per acre, and in four of the eleven trials the increase was secured from the potash alone costing less than half as much as the complete fertilizer.

In eight series of experiments with corn there was

only one case where the increased yield paid for the fertilizer. It would appear that corn is not at present a crop upon which commercial fertilizers can be advantageously used.

On old wheat lands phosphate and potash fertilizers can be used to better advantage than either nitrogen alone or a complete fertilizer. If clover is seeded with wheat that has received a dressing of potash or phosphate fertilizer often a better crop of clover results, and thus additional value is secured from the fertilizer. In the building up of old wheat lands the first thing is to determine by trial on a small scale the extent to which commercial fertilizers increase the yield. In case the increase is sufficient to pay for the fertilizer it should be used, as the influence upon following crops will be more than sufficient to pay for the labor.

Commercial fertilizers should be used in connection with crop rotation, farm manures and clover production, rather than as the only means of increasing fertility. When judiciously used they have a proper place in our agriculture, but when indiscriminately used it is generally at a financial loss.

INFLUENCE OF FERTILIZERS UPON THE COMPOSITION AND QUALITY OF WHEAT.

HARRY SNYDER.

Well known factors which influence not only the yield but the quality of wheat are fertility of the soil, character of the seed and climatic conditions. In the preceding article the influence of fertilizers upon the yield of the crop was discussed. In this article their influence upon the composition and quality of the grain is considered. A number of samples of grain grown upon the fertilizer plots were procured, and these were milled into flour under chemical control in the experimental flour mill of the Minnesota Experiment Station. Chemical analyses were made of the wheat samples, and bread making and technical tests of the flour from these samples. At each place where the fertilizer tests were carried on the several plots receiving the fertilizers were treated alike in all respects except as to kind of fertilizer applied. Hence the factors, seed and climate are identical and any differences in the composition and bread making quality of the wheat must be ascribed to variations in the fertility of the soil, resulting from the fertilizers.

In many instances the fertilizers exerted some special influence upon the growth of the crop, as nitrogen used alone retarding maturity, and minerals used alone hastening maturity. In some cases, size and character of the kernels were influenced by the fertilizers. Larger, better filled, and better colored grain generally, resulted from their use, particularly where the fertilizers perceptibly increased the yield. In eight trials the phosphate fertilizer increased the weight of the grain per bushel and in two trials the weight was the same as when no fertilizer was used. In five trials potash increased the weight per bushel and in no case was the weight decreased by the application of potash. In some cases the nitrogen fertilizer increased and in others decreased the weight.

The weight per bushel, character of the kernels, chemical composition of the grain, and the results of the bread-making and technical tests of the flour are given in the following tables. In the milling and bread making

TABLE I.—Influence of Fertilizers upon the Weight per Bushel of Wheat, and Character of the Kernels.

Source	Kind of Fertilizer.	Wt. per bu. lbs.	Character of Kernels.
Ziemer	No Fertilizer	56	Kernels not well filled—uneven.
"	Nitrogen	57	Like no fertilizer, but a little darker.
"	Potash	58	Well filled—good color—some starchy.
"	Phosphate	58	Medium size—good color—few starchy.
"	Complete	58	Like potash plot.
Uhlhorn	No fertilizer	56½	Uneven in size—some not well filled.
"	Nitrogen	56	Better filled than no fertilizer, and more amber colored.
"	Potash	58	Well filled—medium sized and even, some starchy kernels—good color.
"	Phosphate	57½	More amber colored than potash—less starchy.
"	Complete	56½	Like phosphate but not as good in color, more of a "dead" color.
Boss	No fertilizer	55	Some shrunken, uneven, "dead" color.
"	Nitrogen	56	Like no fertilizer but darker.
"	Potash	58	Medium sized—bleached appearance.
"	Phosphate	58½	Even—fairly well filled, but lacking in amber color.
"	Complete	60	Like potash.
Univ. Farm	No fertilizer	59½	Fairly uniform, light colored.
" "	Nitrogen	60	Darker amber than no fertilizer.
" "	Potash	59½	Tendency to form "starchy kernels."
" "	Phosphate	59½	Smaller and more amber than potash.
" "	Complete	60	Like nitrogen plot.
Beeson	No fertilizer	53	Not well filled, many of "dead" color.
"	Phosphate	55	Better color and kernels plumper than no fertilizer.
"	Complete	56	Like phosphate plot.
Hummel	No fertilizer	57	Kernels small, glutinous.
"	Potash	57	Kernels more plump than no fertilizer, also better color —glutinous type.
"	Phosphate	57½	
Olson	No fertilizer	56	Kernels small and uneven.
"	Nitrogen	56	Larger, more glutinous than no fertilizer.
"	Phosphate	56½	Glutinous, but of "dead" color.
"	Potash	56	Like phosphate.
"	Complete	56	Like nitrogen.

TABLE I.—Influence of Fertilizers upon the Weight per Bushel of Wheat, and Character of the Kernels.—(Continued.)

Source	Kind of Fertilizer.	Wt. per bu. lbs.	Character of Kernels.
Johnshoy	No fertilizer	55	Small, some only partially filled, "blighted."
"	Nitrogen	55	Some a little green—uneven in size—not well filled.
"	Potash	56	Uneven—better color, higher maturity than nitrogen.
"	Phosphate	56	Glutinous—better color, more amber than potash.
"	Complete	56	Like potash.
Strand	No fertilizer	57	Fair color—kernels not of high maturity.
"	Nitrogen	57	But little difference between kernels from various plots.
"	Potash	58	
"	Phosphate	58	
"	Complete	58	
Schain	No fertilizer	57	Some kernels not well filled.
"	Nitrogen	55 ½	Maturity retarded—slightly green in color.
"	Potash	57 ½	A slight improvement in color and filling over nitrogen plot.
"	Phosphate	57 ¾	
"	Complete	55 ½	

tests the same methods were employed as are described in former bulletins of this station.

The fact that the amount and kind of plant food in the soil influence the physical characteristics of the grain is indicated in a number of the trials. In general the heaviest weight and best quality of wheat was produced on the fertilized plots. In some of the tests, the phosphate, and in others the potash fertilizer exercised the greatest influence upon the quality of the grain, as to weight per bushel and uniformity of kernels. Nitrogen alone did not exert as great an influence toward improvement of the kernels as the mineral elements alone; in a few instances, however, nitrogen alone improved the glutinous character and general appearance of the grain.

From the tests made upon the different soil types of the state it would appear that fertilizers may improve the quality of the grain, but the kind of fertilizer elements as potassium, or phosphorus required for purposes of improvement depends entirely upon the individuality of the soil upon which the wheat is grown. Improvement in quality of the grain follows as a result of increase in the fertility of the soil, and a soil must be built up in the elements it lacks and these must be ascertained by experiments. In many localities where the experiments were made in 1906, the climatic conditions were unfavorable, but it is to be noted that with the more liberal supply of plant food in the fertilized plots the quality of the grain as to weight per bushel, plumpness, maturity and uniformity of kernels was better than on the unfertilized plots. This would indicate that during unfavorable seasons crops produced upon soils of low fertility are more susceptible to the adverse climatic conditions than crops grown upon soils of high fertility. In the following tables chemical analyses are given of sixty samples of wheat raised upon the various experimental plots. The analyses were made according to the methods of the association of Official Agricultural Chemists by Mr. Lewis O. Bernhagen, Laboratory Assistant.

TABLE II.—Composition of Wheat Raised on Experiment Plots.

Source.	Kind of Fertilizer.	Moisture.	Ash.	Ether Extract	Protein.	Crude Fiber.	Carbohydrates.
A. Boss	Phosphate	12.23	1.67	2.64	11.14	2.92	69.40
"	No fertilizer	12.56	1.59	2.34	11.45	2.89	69.17
"	Potash	13.95	1.63	2.45	10.79	2.62	68.56
"	Nitrogen	15.42	1.53	2.36	11.11	2.89	66.69
"	Complete	14.16	1.54	2.48	10.60	2.64	68.58
University Farm	Phosphate	13.31	1.71	2.01	11.66	2.00	69.31
"	No fertilizer	13.43	1.70	1.97	11.58	1.99	69.33
"	Potash	13.84	1.81	2.01	11.43	2.33	68.58
"	Nitrogen	13.81	1.68	1.94	11.90	1.96	68.71
"	Complete	13.46	1.69	1.83	12.43	2.11	68.48
R. Dalley	Phosphate	7.73	1.87	1.91	12.94	2.88	72.67
"	No fertilizer	7.49	1.78	2.32	12.43	2.93	73.05
"	Potash	7.96	1.71	2.12	12.86	2.82	72.53
"	Nitrogen	7.83	1.68	2.07	12.96	3.10	72.36
"	Complete	7.61	1.87	1.91	12.34	3.05	73.22
O. O. Uhlhorn	Phosphate	12.05	1.51	2.13	12.57	2.56	69.18
"	No fertilizer	12.01	1.32	2.02	13.17	2.89	68.59
"	Potash	12.00	1.37	2.25	13.01	2.60	68.77
"	Nitrogen	11.78	1.33	2.20	14.08	2.20	68.41
"	Complete	10.98	1.57	2.65	13.03	2.91	68.86
H. Johnshoy	Phosphate	10.21	1.76	2.38	14.01	2.90	68.74
"	No fertilizer	10.56	1.47	2.23	13.55	3.30	68.89
"	Potash	10.65	1.40	2.18	13.62	2.78	69.37
"	Nitrogen	10.23	1.56	2.35	14.57	3.04	68.25
"	Complete	11.54	1.49	2.65	13.70	3.34	67.28
C. M. Beeson	Phosphate	10.45	1.75	2.37	12.44	3.02	69.97
"	No fertilizer	9.70	1.50	1.81	13.12	2.90	70.97
"	Potash	7.09	1.53	2.00	13.17	2.93	73.28
"	Nitrogen	7.20	1.40	1.99	14.61	3.02	71.78
"	Complete	9.95	1.56	2.17	13.12	2.72	70.48
J. F. Ziemer	Phosphate	10.11	1.62	2.28	12.92	2.56	70.51
"	No fertilizer	11.00	1.80	2.38	13.52	2.77	68.53
"	Potash	9.96	1.39	2.15	13.00	2.61	70.89
"	Nitrogen	11.33	1.49	2.30	13.77	3.00	68.11
"	Complete	11.04	1.63	2.20	13.87	2.57	68.69
A. K. Strand	Phosphate	10.38	1.92	2.20	13.14	3.08	69.28
"	No fertilizer	9.73	1.63	2.08	13.71	2.62	70.23
"	Potash	9.24	1.73	2.09	13.82	2.93	70.19
"	Nitrogen	10.18	1.43	2.23	13.91	3.08	69.17
"	Complete	9.83	1.80	2.24	13.91	2.76	69.46
Unknown	Phosphate	13.26	1.61	2.17	12.71	2.73	67.52
"	No fertilizer	11.01	1.66	2.14	13.06	2.38	69.75
"	Potash	13.34	1.67	1.96	12.88	2.35	67.80
"	Nitrogen	12.77	1.59	2.15	13.62	2.57	67.30
"	Complete	12.75	1.73	2.24	13.04	2.88	67.36
J. T. Schain	Phosphate	7.65	1.80	2.16	12.96	2.67	72.76
"	No fertilizer	7.77	1.75	2.00	13.51	2.65	72.32
"	Potash	7.80	1.75	2.04	13.14	2.56	72.71
"	Nitrogen	7.13	1.80	2.17	13.89	2.79	72.22
"	Complete	7.92	1.77	2.21	14.11	2.68	71.31
Geo. Hummel	Phosphate	10.90	1.69	2.19	12.73	2.55	69.94
"	No fertilizer	10.13	1.61	2.34	13.59	2.66	69.67
"	Potash	10.69	1.60	2.19	14.00	2.54	68.98
"	Nitrogen	6.46	1.61	2.08	14.19	2.59	73.07
"	Complete	6.10	1.77	2.23	14.02	2.55	73.33
O. M. Olson	Phosphate	6.35	1.83	1.82	12.64	2.85	74.51
"	No fertilizer	6.58	1.85	1.68	13.82	2.68	73.39
"	Potash	6.37	1.79	1.81	14.52	2.69	72.82
"	Nitrogen	6.28	1.83	1.97	14.91	2.66	72.35
"	Complete	6.47	1.86	1.85	14.86	2.87	73.09

In all of the tests except one, the highest percentage of nitrogen was secured from the wheat grown upon the plots receiving either nitrogen alone or the complete fertilizer of which nitrogen formed a part. A similar result

was secured in 1905 from a more limited number of trials. Increasing the supply of nitrogen in the soil increases the amount of nitrogen in the grain. As previously noted this increase in nitrogen alone, unless associated with the mineral elements may result in a poorer quality of grain, for while nitrogen alone increases the crude protein content of the grain, to secure improvement in quality as well, the nitrogen must be associated with the other essential elements of plant food. The results indicate that it is possible to increase the protein content of wheat one per cent or more through the use of fertilizers, and also to secure an improvement in the quality.

The influence of the nitrogenous fertilizers upon the form of the nitrogen in the wheat was also studied. A number of investigators have reported the presence of nitric nitrogen in plants. King and Whitson, in the Eighteenth Annual Report of the Wisconsin Experiment Station, page 220, state that in the case of oats in the "milk stage," grown on soil very rich in nitrates, 2.64 per cent of nitrogen was obtained by the ordinary Kjeldahl method, but when the method was modified to include nitrates, 3.12 per cent was obtained. They also report nitric nitrogen in corn and potatoes.

For the purpose of determining the amount of nitric and other forms of nitrogen in the wheat fertilized with nitrate of soda, three samples were selected—wheat grown at University Farm, at Benson and at Pipestone. The results of the analyses are given in the following table:

TABLE III.—Forms of Nitrogen in Wheat Fertilized With Nitrate of Soda.

	Wheat from Univ. Farm Per cent.	Wheat from Benson Per cent.	Wheat from Pipestone Per cent.
Nitrogen (Kjeldahl process)	1.90	1.77	2.07
Albuminoid nitrogen	1.78	1.68	1.98
Nitrogen (modified to include nitrates)	2.01	1.86	2.22
Excess of modified over Kjeldahl process (nitrates?)	.11	.09	.15
Nitrogen as nitrites	.00006	.00004	.00008

When the nitrate of soda was used as a fertilizer a small amount of nitric nitrogen was found to be present in the wheat. The albuminoid nitrogen and the modified nitrogen determinations show that not all of the nitrogen

in the plant is present as proteids. Qualitative reactions of all of the flours made from the wheats fertilized with nitrate of soda and organic nitrogen showed the presence of nitric nitrogen and also traces of nitrites. Some of the wheats grown upon the plots where there was no nitrogen in the fertilizers gave the same reactions, while others did not. The nitrogen content of the wheat was increased by applications of nitrogenous fertilizers to the soil, but as previously stated the bread making qualities of the flour made from such wheat are not necessarily improved. Similar results have been reported by Hall of the Rothamsted Station: "Again, as we have seen, 'strength' is generally associated with a high nitrogen content, yet the wheats grown on some of the Rothamsted plots, where so large an excess of nitrogenous manure is applied that even the grain becomes more nitrogenous, instead of becoming stronger only gets incredibly weaker. It is quite evident that the form as well as the amount of nitrogen must be taken into consideration in studying the bread making qualities of flour.

In all of the comparative bread making tests the same amounts of flour, yeast, and other materials were used and the breads were made under uniform conditions by Miss Ruth Holmberg. The results of the baking tests are given in the following table.

TABLE IV.—Bread Making Value of the Flours.

Source.	Kind of Fertilizer.	Dry Gluten per cent.	Size of Loaf.	Remarks	Per cent. of water absorbed.	Protein, per cent. (flour).
O. Uhlhorn	Complete	12.9	21⅝x16¾	White, fine grained	47.66	12.21
" "	Nitrogen	14.2	20¾x15⅞	Same as potash and no fertilizer	45.00	13.34
" "	No fertilizer	13.16	20⅞x15⅝	Fairly good grain and color	41.33	12.62
" "	Phosphate	12.7	21 x15¾	Good grain, darker color	41.00	12.15
" "	Potash	12.7	20¾x15⅝	Same as no fertilizer	41.33	12.98
" "	Duplicate complete		21⅛x16¼	Whiter than no fertilizer, good grain		
" "	Duplicate No fertilizer		21⅝x16⅝	White, good grain		
O. M. Olson	Complete	13.6	21¼x16⅝	Rather dark, fairly good grain	46.66	12.20
" "	Nitrogen	13.7	20⅝x15¼	Darkest, coarsest grained	45.33	12.65
" "	No fertilizer	13	20½x15⅝	Much like complete, only whiter	45.33	12.17
" "	Phosphate	13.6	20¾x16	Like potash	43.33	11.61
" "	Potash	14.1	20¾x15½	Rather dark, fairly good grain	45.66	12.49
" "	Duplicate Nitrogen		20⅞x15¾	Dark, heavy, poor grain		
" "	Duplicate complete		21⅝x16½	Fairly good color and grain		
H. Johnshoy	Complete	13.6	20⅞x15¼	Fairly good grain, dark	50.00	13.48
" "	Nitrogen	15.7	20½x15	Darker, coarse grained	49.66	13.60
" "	No fertilizer	14	20¾x15½	Same as nitrogen	53.00	12.94
" "	Phosphate	14	21¼x16¾	Good grain, whitest	53.00	12.86
" "	Potash	13.9	20 x15	Same as complete	48.33	11.80
" "	Duplicate Phosphate		21⅝x16¾	White, good grain		
" "	Duplicate No fertilizer		20¾x15⅝	Darker, fairly good grain		
J. T. Ziemer	Complete	12.8	20½x15¼	Rather dark, fair grain	50.66	11.86
" "	Nitrogen	15	20½x15¾	Darker than potash, but finer grained	45.00	12.96
" "	No fertilizer	13.9	20¾x15¾	Dark, medium grain	47.66	12.31
" "	Phosphate	14	21 x16	Dark, coarse grained	45.66	12.22
" "	Potash	14	21 x16	Whitest, fine grained	50.33	12.15
" "	Duplicate Potash		20¾x15⅞	White, good grain		
" "	Duplicate complete		20½x15¾	Same as potash		
Univ. Farm Plot 5	Complete	13.5	21 x15⅞	Dark, coarse grained	52.33	10.96
Univ. Farm Plot 2	Nitrogen	11.6	21 x16	White, good grain	46.66	11.40
Univ. Farm Plot 1	No fertilizer	11.02	20⅝x15¼	Coarse grained, dark	51.00	10.37
Univ. Farm Plot 4	Phosphate	12.01	20½x15⅛	Dark, coarse grained	46.33	11.04
Univ. Farm Plot 3	Potash	11.3	21 x16⅛	Dark, coarse grained	46.66	9.97

TABLE IV.—Bread Making Value of the Flours.—(Continued.)

Source.	Kind of Fertilizer	Dry Gluten per cent.	Size of Loaf	Remarks.	Per cent. of water absorbed.	Protein, cent.
Univ. Farm Plot..	Duplicate no fertilizer.....		20 3/4 x15 3/4	Darker, rather coarse grained		
" "	Duplicate Nitrogen		21 1/8 x16 1/2	Very white, fine grained, fluffy		
A. K. Strand	Complete	14	21 x15 3/4	White, good grain	48.00	12.32
" "	Nitrogen	13.6	21 x16	Whitest, smooth loaf, good grain	48.66	13.09
" "	No fertilizer	13.1	21 3/4 x17	Largest loaf, 3rd in color, good grain	44.66	12.32
" "	Phosphate	13.5	20 1/4 x15 1/2	Darker than potash, same grain	44.66	
" "	Duplicate no fertilizer		21 x16 1/2	Good grain and color		
" "	Duplicate Phosphate		20 1/2 x15 5/8	Good grain and color		
" "	Potash	14	21 x15 3/4	Good grain and color	45.00	12.43
A. Boss	Complete	11.4	20 3/4 x15 1/2	Fairly good color and grain	46.00	10.84
" "	Nitrogen	11	20 3/4 x15 1/2	Fairly good color and grain	46.66	10.00
" "	No fertilizer	10.7	21 x15 3/4	Fairly good color and grain	44.00	10.26
" "	Phosphate	10.8	20 7/8 x16	Whitest, good grain	43.66	10.27
" "	Potash	11.4	20 1/4 x15 1/2	Same as first three	46.66	9.86
G. Hummel	No fertilizer	13.7	20 3/4 x15 5/8	Trifle darker than the other two, good grain	49.33	12.47
" "	Potash	13.8	20 3/4 x16	Very white, good grain	46.33	12.94
" "	Phosphate	12.3	20 3/4 x16	Very white, good grain	48.33	11.82
" "	Duplicate Phosphate		21 1/8 x16 1/2	Good color and grain		
" "	Duplicate No fertilizer		21 1/4 x16 1/4	White, fine grained		
Beeson	No fertilizer	12.5	20 1/8 x16 3/8	Trifle darker than phosphate, good grain	51.66	11.62
" "	Phosphate	11.5	21 3/8 x16 3/4	Good color and grain	54.00	11.60
" "	Complete	12.8	20 3/4 x15 1/2	Good color and grain	61.33	12.66
" "	Duplicate complete		20 1/2 x15 5/8			
" "	Duplicate Phosphate.....		22 x17 1/8	Very white, good grain		

In all there were tested forty-one samples of flour milled from wheat grown upon the fertilized and unfertilized experimental plots at nine different places. The wheat from three of the nine places, grown upon the plots

1 2 3 4 5 6

Fig. 3.—Breads made from wheats grown with and without fertilizers.

1. Phosphate. 2. No fertilizer. 3. Complete. 4. Potash (all Ziemar plots). 5. Potash. 6. No fertilizer. Nos. 5 and 6. Liggett, Benson plots.

1 2 3 4

Fig. 4.—Breads made from wheats grown with and without fertilizers.

1. No fertilizer. (Univ. farm.)
2. Nitrogen.
3. Phosphate.
4. No fertilizer. (Johnshoy.)

fertilized with phosphates, produced flour that made the best bread. From two of the places the wheat fertilized with nitrogen made the best bread; from two fertilized with potash, and from two the complete fertilized wheat.

In thirty of the forty-one tests the fertilizers which gave the largest yields per acre produced wheats of the highest bread making value, while in ten of the tests the best quality of flour was secured from the fertilized wheats which did not show the largest yield per acre. While yield and bread making quality are both improved by the use of fertilizers they are not necessarily both improved to the same extent by the same fertilizer.

There appears to be no constant relationship between the per cent of protein in the grain and flour and the bread making value, and while it is possible to increase the amount of proteids in flour by the use of nitrogenous fertilizers the bread making value of the flour is not proportionately increased. In many instances the increase in nitrogen content imparts a negative value, as a part of the nitrogen is in non-proteid forms.

The experiments taken as a whole show that not only the yield of wheat but also the bread making value can be enhanced by increasing the fertility of the soil, and that there is a very close relationship between the amount of available plant food in the soil and the quality of the wheat produced upon the soil and its bread making value.

A COMPARISON OF CHEMICAL METHODS WITH FIELD TESTS FOR DETERMINING THE FERTILIZER REQUIREMENTS OF SOILS.

HARRY SNYDER.

Samples of soil were taken from the different places where the fertilizer tests were made, with the view of comparing the results secured by chemical methods with those obtained by the field tests. Various chemical methods have been proposed for determining the available plant food of soils. Some of these have been tested by the Association of Official Agricultural Chemists and while no method has as yet been found that is entirely satisfactory, and that will determine absolutely the available plant food of all soils, some of the methods have proved of much value in studying soil problems. A method that is being tested by chemists employs dilute nitric acid (fifth normal) to dissolve the more active and available phosphoric acid and potash of the soil. The amounts of these are determined by chemical analysis.

Soils are frequently sent to experiment station laboratories with the request for an analysis to determine what fertilizers are needed, and what crops are most suitable for that particular soil. While chemical and physical analyses of soils will not always enable positive answers to be given to these and other similar questions, such analyses are of very great assistance in suggesting what fertilizers are most suitable for trial and the proper treatment to be given in order to make the soils more productive.

With the view of obtaining data upon the available plant food of soils, the phosphoric acid and potash soluble in fifth normal nitric acid were determined at twenty-one of the different places where the fertilizer tests with wheat and corn were carried on. The method followed in the analysis of the soils is described in the report of the Association of Official Agricultural Chemists. Corrections were made for the acid neutralized by the lime and other alkaline matter in the soils.

The analyses were made by Mr. A. D. Wilhoit, Assistant in Soils. The results are as follows:

TABLE V.—Phosphoric Acid and Potash of the Soil Soluble in Fifth Normal Nitric Acid.

	Location of Wheat Plots.	Parts per million of soil.		Bushels wheat per acre. Increase from use of fertilizers			
		Phosphoric acid.	Potash.	Potash.	Phosphoric acid.	Nitrogen.	Complete.
1.	A. K. Strand, Ada	652.6	296.5	No increase.			
2.	J. F. Ziemer, Waltham	25.62	152.0	8	4¾	−½	9½
3.	N. E. Experiment Station	364	207.4	¾	−2½	−3	¼
4.	A. Boss, Benson	387	224	6	0	4	8
5.	University Farm	255	216.5	2.2	−2	1.4	4.2
6.	N. O. Evenson, Litchfield	169	218.9	No increase.			
7.	Geo. Hummel, Langdon	26.5	215.9	5	4	1½	2¾
8.	James Frank, Warren	580	732.1	No increase.			
9.	L. A. Larson, Ulen	259.7	204.1	No increase.			
10.	H. Johnshoy, Starbuck	83.25	247.2	3½	6½	½	9
11.	O. Uhlhorn, St. James	266.8	157.1	2½	5½	1⅛	6
12.	M. B. Lund, Vining	293	248.4	4			
13.	R. Dailey, Pipestone	116.7	312.5	No increase.			
14.	J. T. Schain, Browns Valley			6	7	4	8

TABLE V.—Phosphoric Acid and Potash of the Soil Soluble in Fifth Normal Nitric Acid.

	Location. Soil from corn plots.	Parts per million of soil.	
		Phosphoric Acid.	Potash.
15.	L. A. Sweet, Fairmont	211.7	165
16.	Matthew Frame, Northfield	40.4	353.3
17.	H. A. Ludtke, Amboy	22.9	315.7
18.	E. P. Squire, Hanley Falls	44.8	219.8
19.	S. R. Houlton, Elk River	264	137.5
20.	J. E. Galloway, Austin	56.9	139.7
21.	C. E. King, Spring Valley	35.6	100.4

In the table giving the results of the wheat experiments it is to be noted that where phosphate fertilizers caused an increase in the yield of wheat, with one exception, No. 11, the soils yielded from 25 to 83 parts per million of soluble phosphoric acid. The soils with low solubility of the phosphoric acid, were benefited by application of phosphate fertilizers. In all the trials, with the one exception noted, where the phosphate fertilizers failed to give an increase, the soil contained over 150 parts per million of phosphoric acid soluble in fifth normal nitric acid. The soils from the Red River Valley contain large amounts of soluble phosphoric acid and the wheat

yields on these soils were not increased by phosphate fertilizers.

In the fertilizer experiments with potash the soil (No. 2) yielding the smallest amount of acid soluble potassium produced a large increase when this element was applied, while the one with the largest amount (No. 8) gave no increase with a potash fertilizer. With some of the soils which field tests showed to be deficient in both potash and phosphoric acid, conflicting laboratory results were secured. In some cases where the acid phosphate increased the yield, a low per cent of soluble potash was noted. It is believed that the gypsum present in the acid phosphate exerted its well known indirect action upon the soil and liberated enough potash to assist in the growth of the crop, and so while the field tests indicated mainly a deficiency of phosphates there was also a deficiency in available potash which was not revealed by the field tests. The chemical tests showed a deficiency of phosphates more distinctly than a deficiency of potash. With the one exception noted (No. 11) the chemical tests and the field tests gave identical results, as far as indicating deficiency of phosphates was concerned.

The availability of the plant food in soils is a matter of great importance in agriculture, and to make the plant food available is one of the chief objects of thorough cultivation. Rotation of crops and the use of farm manures and commercial fertilizers also aid in bringing about the necessary physical and chemical changes in the soil that render the plant food more soluble and available. Many of the soils upon which these experiments were performed contain upwards of 4000 pounds per acre of phosphoric acid to the depth of one foot. Average crops of wheat and other grains remove from 20 to 25 pounds per year, indicating that as far as total phosphoric acid is concerned many soils contain sufficient amounts for crop growth but the difficulty is that only a small part of the phosphoric acid is in an available condition. It has been shown by experiments made at this station and reported in former bulletins that the loss of humus from the soil has affected not only the nitrogen content but also the chemical combination of the mineral elements particularly the phosphates. In the presence of the necessary alkaline matter the phosphates and other minerals unite with the

organic compounds produced from the decay of the humus and form humates which are valuable forms of plant food. Hence it is that good cultivation and right systems of farming assist in maintaining the supply of available plant food in the soil. Many soils which have been under cultivation for only comparatively short periods, and which show upon analysis quite large amounts of plant food but give poor crop returns need better cultivation and systems of farming rather than the extensive use of commercial fertilizers.

On some soils the rate of decay of the mineral matter is too slow to furnish a liberal supply of plant food, even when crops are rotated and some farm manure is used and good cultivation is given. In such cases commercial fertilizers are necessary as rotation of crops only hastens instead of retarding the exhaustion of the fertility. Soils of the highest and most lasting fertility are of good texture and contain a liberal store of total plant food derived from minerals which, when the soil is cultivated, decay with sufficient rapidity to furnish the necessary available plant food to crops.

The accumulated plant food is often sufficient to last for long periods of cultivation without material decline in crop yield. There are but few soils, however, so constituted that they are capable of producing continually maximum yields without fertilizers. When the accumulated fertility is exhausted crops are dependent upon the natural fertility of the soil,—that derived from the decay of the mineral and vegetable matter, and generally insufficient to produce good crops. In the farming of new lands early provision should be made to conserve the fertility of the soil.

CORRECTIONS TO BULLETIN No. 101.

Page 237, line 32, nitrogen free extract read 57.36, not 57.45; pages 241 and 242, timothy hay over ripe and prairie hay average quality, add results on dry matter basis; p. 244, to analyses of wild barley add crude fiber 32.20 4 and 36.60; page 244, pigeon grass protein read 16.28, not 16.23; page 248, 4th line, fiber read 33.54, not 32.54; page 251, sample 8, nitrogen free extract, read 55.26, not 55.36; page 252, ash read 7.06, not 7.16.

CORRECTION TO BULLETIN No. 89.

Page 193, line 17, and page 194, line 21, read: to the depth of three-fourths of one foot, not "to a depth of one foot."

CORRECTIONS TO BULLETIN No. 85.

Page 191, 7th mds. carbohydrates read 75.92, not 79.92; page 208, dry matter: No. 79, read 89.10, not 89.18; No. 86, 85.68, not 87.68; No. 79, 87.85, not 87.89; protein, No. 83, read 15.44, not 15.40; No. 87, 14.07, not 14.17; No. 100, 16.43, not 16.33.

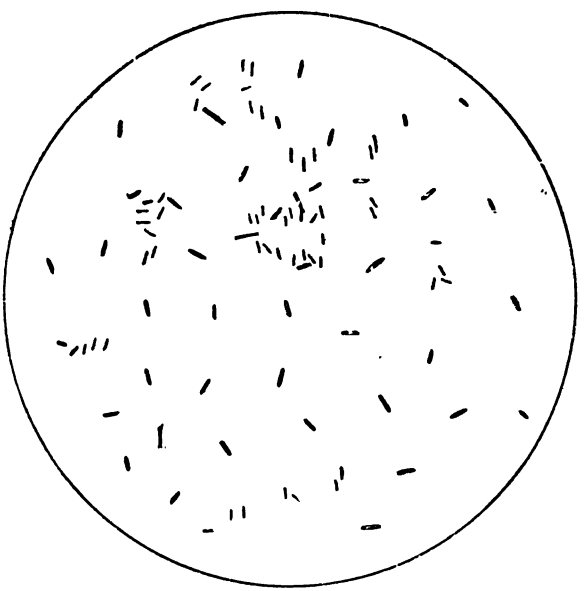


Figure A.—ACID-FAST BACILLI.
Presumably of Tuberculosis in Cover Glass Smears from the Intestinal Mucous Membrane of the Cow, Reddie.

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DISSEMINATION OF TUBERCULOSIS BY THE MANURE OF INFECTED CATTLE

BY

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AND

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OBJECTS OF THE WORK HEREIN REPORTED.

The general purpose was to secure information concerning the ways in which tuberculin reacting cows pass off tubercle bacilli aside from bronchial secretion by coughing, and in milk. For this purpose the following was undertaken:

First. To study the manure of tubercular cattle.

Second. To study nasal secretion of tubercular cattle.

Third. In case the work with either manure or nasal secretion or both gave positive results, to determine whether such discharge of tubercle bacilli is constant, or intermittent and irregular.

Fourth. To determine if possible whether there is any clinical evidence associated with discharge of tubercle bacilli in the manure, particularly with reference to an accompanying diarrhea.

When this work was begun there was an abundance of information concerning methods by which infection of tuberculosis might be taken into the animal or human body, and such information is still accumulating rapidly. There was very little information that could be considered reliable concerning the methods by which the infection may be given off by the tuberculous animal, aside from spraying of bronchial discharges in the act of coughing and through milk.

Comparatively few tuberculous cattle cough to an unusual extent, and, there seems slight probability that there may be serious spread of tuberculosis among mature cattle from virulent milk, yet, rapid spread of this disease in the stable is a matter of commonest occurrence. If there are

other means of discharging the infection: for instance, in the manure, or urine, or nasal secretion, then these become at once matters of serious concern; serious alike for confined animals, and for exposed people. Our work has been under consideration for several years and was actively begun early in March, 1905.

It is not pleasant to estimate what may easily happen if tubercular cows pass virulent manure, and are present in a city dairy, in a breeding herd, or in any herd of milk cows. Manure readily becomes smeared upon the tail, thence, upon the udder and flank, where it becomes dried. Particles are broken off and fall into the milk pail, and the milk has become seriously contaminated. To make a serious case it is not necessary to suppose that such manure reaches the udder or flank. It may become dried on the floor, and particles may then float as dust in air currents, caused by animals and people walking about the floor or air currents from open doors and windows. Such particles may easily settle into milk pails or calf pails or upon the food of the older cattle. Persons in the stable may inhale such dust. Virulent manure from cows may still be considered infectious even if it be shown that there is slight danger from dried, human sputum.

The possible contamination of past ures with virulent manure appears to be an important consideration. The Experiment Station has recently completed certain experiment work, undertaken with a view of estimating the probability of outdoor transmission of the disease, which work will be reported in the near future.

There are other reasons emphasizing the importance of such investigation. We cannot intelligently consider the spread of this disease unless probable sources of infection are known. The impression seems to be gaining general acceptance that infection frequently occurs very early in life and by the way of the digestive tract. If this opinion be correct, then tuberculous manure becomes at once a serious consideration for young children; and for calves that are raised upon dams whose udders and teats and the milk itself may easily become contaminated and dangerous.

Frequent and thorough disinfection of the floors in a stable where tubercular cows are kept, and where it is important to reduce the area of infection and to disinfect all

parts as rapidly as possible becomes a more important consideration, in view of the possibility of such infected manure contamination.

In view of the possibility of dry particles of contaminated manure resting upon the surface of the floor and bodies of confined cattle, sunshine becomes a still more important factor than is commonly supposed. The importance of sunshine is still further emphasized, in view of abundant evidence that it is very destructive to tubercle bacilli.

WORK DONE BY OTHERS.

Dr. Repp reported a very interesting case in a paper before the American Veterinary Medical Association, in 1903, where tubercle bacteria occurred abundantly in the intestinal mucosa and in the smears from the surface of this membrane. Ulcers were present on its mucous surface. Imagine this cow, or a cow with tubercular ulcers on the mucosa like that shown in a certain cut used in Dr. Moore's Pathology of Infectious Diseases of Domestic Animals, being used in any herd of milk cows, especially in a dairy herd.

Schroeder and Mohler[1] fed two healthy cattle a virulent culture of tubercle bacilli, and at the same time fed these cattle heavily on corn, so that corn would be passed in considerable quantity in the manure. This manure was given to an experimental pen of four pigs. Three out of the four hogs became infected with tuberculosis.

In another experiment the same workers used manure from two cattle which were known to be tubercular. This manure was thrown into an experimental pen of four hogs. One of the hogs showed lesions of probable tuberculosis on postmortem. Bearing in mind the fact that hogs are very susceptible to tuberculosis by ingestion, this is seen to be an important experiment upon the custom of running hogs after cattle in the feed lot.

Some time before beginning the experiment reported in this bulletin, one of us (Reynolds) had found innumerable acid-fast bacilli resembling in every way bovine tubercle bacilli in the manure of a cow named Reddie on the University Farm. These bacilli were found also in scrapings from the surface of the rectal mucosa, and in smears from bits of that membrane. (See Fig. A.) This cow, Reddie, had reacted to tuberculin some time before, and had chronic diarrhea which was supposed to be of tubercular origin. It is of course possible that this may have been a case of Johne's disease; and the cow may have been affected with tuberculosis and this other disease, simultaneously, granting that the latter is distinct from tuberculosis.

[1] Bureau of Animal Industry, Bulletin 88.

The cow Reddie was tested with tuberculin as shown by the following records:

(I.) Weight, 1450; dose 3.5 c.c.; bureau tuberculin; injected at 9 p. m., Jan. 29, 1902.

	6 a.m.	8 a.m.	10 a.m.	12 m.	2 p.m.	4 p.m.	6 p.m.	8 p.m.
Jan. 29			101.2		101.1	101.2		101.3
Jan. 30	105	102	105	106	105	105	104	

Diagnosis, tuberculosis.

(II) Weight, 1,430; dose, 3.75 c.c.; bureau tuberculin; injected at 9 p. m., April 8, 1902.

	6 a.m.	8 a.m.	10 a.m.	12 m.	2 p.m.	4 p.m.	6 p.m.	8 p.m.
Apr. 8		100.1	101.1		101.5		101	101
Apr. 9	102.5	104.8	106.2	105.3	105	103.3	103.8	

Diagnosis, tuberculosis.

(III) Weight, 1,300; dose, 3.8 c.c.; bureau tuberculin; injected at 9 p. m., May 27, 1903.

	6 a.m.	8 a.m.	10 a.m.	12 m.	2 p.m.	4 p.m.
May 27			100.9		101.4	101
May 28	105.4	105.2	104.6	104.7	104.8	104.4

Diagnosis, tuberculosis.

HISTORY AND AUTOPSY OF COW REDDIE.

This was a grade short-horn cow brought to the university farm in 1901, from Toronto, Can., where she had taken sweepstakes prize. She was tested for tuberculosis on the following dates, and reacted each time: Jan. 29, 1902; April 29, 1902; May 28, 1903;

This cow was a good breeder and very valuable, and was therefore retained in the herd for a time for this purpose.

Her general conditions remained good until June, 1903, when she began to decline. The cow gradually lost flesh and general condition until about October, 1903, when she commenced to gain back the lost weight, making a gain of about 150 pounds in 3 months. After this there came another decline. By the middle of February, 1904, she had begun a noticeable decline in general health and failed rather rapidly. She died March 10, 1904. The first symptom of the second decline was a severe diarrhea which persisted until death. Her temperature ranged during this time from 105 to 107, with fast and weak pulse. Edematous, swellings occurring behind the left elbow, under the brisket, and between the jaws. The appetite remained fairly good until the latter part of her illness.

Autopsy.—March 11, 1904, Reddie, 7 to 8 years old, weight about 1,400 pounds, still in fairly good flesh. She was last tested with tuberculin on May 28, 1903, and reacted. The post pharyngeal, mesenteric, and mediastinal glands, also one supra mammary lymph gland and several bronchial glands were all more or less badly involved with tuberculosis lesions. Both small and large intestines showed small nodules which were supposed to have been tuberculous, but were not tested for virulence or for bacilli. The spleen and liver showed plain lesions of tuberculosis, also the costal, diaphragmatic, and visceral pleurae (membrane lining the chest cavity) were all involved. The lungs were very generally affected, the disease involving both lungs and all the lobes.

Microscopic examinations of a considerable number (16) of cover glass smears were made from various affected structures and areas. Examination of these indicated a very general and very active infection. The word positive in the following list means that bacilli of tuberculosis were found on microscopic examination.

(1) Serum from cut surface of tubercle in active development on costal pleura, positive.

(2) Fluid from calcareous tubercle on costal pleura, negative.

(3) Serum from cut surface of large tubercle in costal pleura, positive.

(4) and (5) Forceps tissue smears from inflamed capsule of large tubercle on costal pleura, positive.

(6) Surface smear from the inflamed capsule of another large tubercle in costal pleura, negative.

(7) Surface smear from another small active tubercle near 6, positive.

(8) Forceps tissue smear from inflamed areas of peritoneum, right side, positive.

(9) Forceps tissue smear from inflamed capsule of tubercle in the lung, positive.

(10) Same as 9, negative.

(11) Same as 9, positive.

(12) Loop smear from surface of intestinal mucous membrane, positive.

(13) Loop smear from intestinal mucous membrane at another point, positive.

(14) Heart blood, negative.

(15) Loop smear intestinal contents, positive.

(16) Forceps tissue smear from intestinal mucous membrane from nearly the same point as number 13, positive.

The forceps tissue smears mentioned above were made by simply tearing out a bit of tissue and making direct smear upon the cover glass.

These bacilli were acid-fast and showed the peculiar staining reaction of tubercle bacilli; they correspond with tubercle bacilli in all details afforded by microscope; came from a cow that had reacted repeatedly to tuberculin, and showed extensive lesions of tuberculosis upon post mortem. They were not tested for virulence, but we are presumably

justified in saying that in all reasonable probability they were bacilli of bovine tuberculosis.

Schroeder and Cotton[2] also have undertaken to secure information concerning methods by which tubercle bacilli are passed off by tubercular cattle. They first made microscopic examinations of manure of tubercular cattle, also of scrapings of the rectal mucous membrane.

Smears made from the manure and rectal scrapings of five out of seven tuberculous cattle examined and of two other healthy cattle which were fed cultures of tubercle bacilli, showed bacilli which were not distinguishable from bovine tubercle bacilli, and were more numerous in the rectal scrapings than in the manure. These preliminary examinations were checked by similar studies of the manure of non-tubercular cattle which did not show such bacilli. The virulence and identity of these bacilli were determined by guinea pig inoculations.

Of seven natural cases, five showed bacilli in the manure on microscopic examination, as mentioned. The manure of these five was tested by inoculation and found infectious in three cases. Three healthy cows were fed culture of virulent bacilli and passed manure containing tubercle bacilli detected by microscopic examination and subsequently proven virulent. They conclude from this experiment that tubercle bacilli pass through the entire digestive tract of the cow without losing virulence.

The same experimenters also did work with saliva, nasal discharge, and urine of two cows, and, with the milk of three, making microscopic examinations in these cases and guinea pig inoculations. Microscopic examinations were all negative except for the saliva of one of the two cows examined in this way. The milk as shown by guinea pig inoculations was free from virulent tubercle bacilli. They conclude that cows rarely or never pass tubercle bacilli in the urine unless the genital or urinary organs are involved. Their results with the nasal secretions both by microscopic and inoculation tests were negative.

These writers estimate that with an average cow passing about thirty pounds of fresh manure per day and calculating upon the basis of the average number of bacilli in each microscopic mount, and the weight of feces smeared upon the covered glass, that such average cow

[2] Bureau of Animal Industry, Bulletin 99.

passing tubercle bacilli would give off 37,800,000 per day that could be demonstrated by the microscope, and it will be easily understood by anybody familiar with such work that there would be several times this number which could not be so demonstrated. They found uniformly that the tubercle bacilli were evenly distributed through the manure.

Schroeder and Cotton[2] are convinced that tubercle bacilli do not from any other source have a wider distribution in a fresh and virulent state than those that enter milk with the fresh manure of tubercular cows. If we remember that practically everybody uses milk every day, and remember the enormous number of tubercle bacilli which a single cow may pass in a day, and that milk may be easily contaminated by indirect as well as direct methods, this conclusion does not appear unreasonable as the reader would naturally conclude at first thought—providing a considerable proportion of tubercular cattle pass virulent manure.

These same writers, Schroeder and Cotton[2], contaminated fresh milk from healthy cows with the manure of cows which were known to be passing tubercle bacilli in this way. They endeavored to make the experiment compare as closely as possible with conditions which would develop in natural stable contamination. The amount of feces used for the samples of the milk was very small, estimated as not more than might easily gain access where average cleanliness in milking was observed.

In some cases the contaminated milk was injected immediately, and in other cases it was first strained through linen cloth. The experiment was properly controlled with similar milk not so contaminated. Five tubercular cows which were known to be passing tubercle bacilli were used for this work. The unstrained milk contaminated by the manure of four of these five cows produced tuberculosis of guinea pigs by injection into the abdominal cavity. The milk contaminated by the feces of these five cows and strained, proved infectious in three cases.

WORK BY THE MINNESOTA EXPERIMENT STATION AND THE LIVE STOCK SANITARY BOARD.

The material for this work was obtained from 45 head of cattle that had previously reacted to the tuberculin test. Twenty-two of these were pure bred, and grade Short-horn, Aberdeen Angus, and Hereford cattle that had been rejected from the University herd on account of their having reacted to the tuberculin test. Some of these animals had been kept in isolation for several years since they first reacted. They had been tested at intervals with tuberculin, and had at all times given reactions. The remaining 23 animals were pure bred Short-horns and grades which were kept upon a stock farm about 25 miles from the experiment station. The majority of these animals had first reacted to the tuberculin test about two years previous to the time this investigation was started. There were a few of these, however, that reacted six months after the first test, and were then stabled with the other tuberculous animals. Some of the cattle from which samples were taken were presumably badly affected as most of them had been known to be tuberculous for about two years, and during this time they had been confined in a barn for at least six months of each year.

Method.—In order to prevent extraneous infection much precaution was taken. In most cases the manure was removed from the rectum after the anus was carefully disinfected and the disinfectant wiped off with cotton. The small experimental animals were guinea pigs, most of which had been previously used for testing diphtheria antitoxin.

The original outline of our work was as follows: One guinea pig to be inoculated each month for four months from each reacting cow; smear preparations to be made at the same time, and stained for tubercle bacilli. After a lapse of six weeks, the guinea pigs were to be killed and a careful post mortem examination held to ascertain whether or not the cow was affected with tuberculosis. As the work progressed, it was found impossible to adhere closely to this plan.

When this work was first started much difficulty was encountered in obtaining manure uncontaminated by other bacteria, etc. The first plan tried was to go to the barn in the morning while the animals were lying down, and obtain the manure as they were made to rise. Usually we were able to obtain a few samples by this method, but much difficulty was experienced in getting samples from the desired animals.

The next method tried was to first wash the anus and surrounding parts with soap and water, then disinfect with alcoholic bichloride, 1-500. The excess of bichloride was wiped off, and a spoon shaped apparatus, see Figure 7, inserted into the rectum for about 10 inches. This was revolved around once or twice and withdrawn. Usually we could obtain the requisite amount of manure by one or two insertions of the spoon. The manure was then scraped from the spoon into a sterile test tube with a glass rod. These samples were taken to the laboratory, smear preparations made from them to stain for tubercle bacilli, and the remainder was used for making a suspension.

During the early part of the experiment 10 c. c. of sterile water was poured into the test tube and about 2 grams of manure triturated with it. The manure was then allowed to settle and a few cubic centimeters of the fluid drawn off by means of hypodermic syringe. This method was found unsatisfactory on account of the large amount of suspended material. We therefore decided to filter it through cotton. In order to do this, the following method was devised: Seven-eighth inch test tubes were heated over a large Bunsen burner until the bottom could be drawn out to a point. The point was then broken, and a small piece of cotton put into the tube and pushed down into the drawn out point. The top of the tube was plugged with cotton and the tube sterilized in the dry air sterilizer at 140-160 degrees C. The suspension of sterilized water and manure was then poured into this funnel and allowed to filter down into another test tube as shown in Fig. 6. By this method it was found that the liquid passed through rapidly and all coarse particles were removed so that the filtrate could be drawn up into a hypodermic syringe through the needle without causing obstruction.

During the early part of the work 5. c. c. of this suspension was injected subcutaneously into guinea pigs, but

TABLE OF ANIMAL INOCULATIONS AND MICROSCOPIC EXAMINATIONS.

Animal's Number	Animal's Name	G. P. Inoculation		Death		Microscope	G. P. Inoculation		Death		Microscope	G. P. Inoculation		Death		Microscope	G. P. Inoculation		Death		Microscope	G. P. Inoculation		Death		Microscope
		Date	Dose	Date	Cause		Date	Dose	Date	Cause		Date	Dose	Date	Cause		Date	Dose	Date	Cause		Date	Dose	Date	Cause	
		1905	C. C.	1905			1905	C. C.	1905			1905	C. C.	1905			1905	C. C.	1905			1905	C. C.	1905		
1	Golden Prince.	Mar. 11	2.	Mar. 13	Sept.	—	Mar. 16	2	July 6	P. M.—	—	July 3	.5	Oct 12	P. M —											
2	Black Bess.	" 16	2.	July 6	P. M.-	—	May 17	1.	" 27	P. M.—	—	July 3	.5	Sept 2	P.M.†††		July 27	.5	Oct 4	Tuberc.	—					
2½	Rosella of Glendale	April 26	2.	" 6	Secondary Inoc. Made P. M. † Peritonitis	—	" 17	1	" 20	" †††	—	July 3	5													
3	Hawthorne I.	Mar. 25	2	Mar. 26		—																				
4	Bonnie Wild Rose	May 24	1	July 17	P. M.--	—						Sept 26	.5	Dec 1	P M.-		Aug. 4	.5	Oct 12	P. M.—		June 30	.5	Oct. 12	P. M.—	
4½	Golden Queen.	April 26	2.	May 5	Sept.	—	May 12	1	May 14	Sept	—	May 17	1	July 26	" —	-	June 30	.5	July 31	P. M.—		Sept. 26	.5	Dec. 5	P. M.—	
5	Dairy A.	Mar 25	2	Mar 27	"	—	April 1	2.	April 5	"	—	April 6	2	April 9	Sept	- -	May 12	2.	May 16	Sept	—	May 17	1.	July 6	" —	-
													1	" 16	"	-										
5½	Dairy B.	" 25	2	" 26	"	—	" 1	2.	" 5	"	—	" 6	2	" 8	"	—	" 12	2.	" 16	"	—	" 24	1.	May 26	Sept.	—
6	Jipsy Girl 2nd .	May 26	1	May 29	Sept	—	June 6	1.	June 7	"	—	June 20	.5	July 24	P. M.-		Sept 26	.5	Dec 5			Aug 4	.5	Oct. 12	P. M.—	
7	Nellie Keillor 2nd.	" 26	1.	July 20	P. M.—	—	Aug. 4	.5	Nov 18	P. M —		" 30	5	Nov. 18	P M -											
7½	Mint Drop 8th	May 26	1	Oct. 12	P. M.—	—	July 3	.5	Oct 12	P. M —	—	Aug 4	.5	" 18	P M -											
8	Bonnie Wild Rose 2nd	May 24	1.	May 26	Sept.	—	July 3	.5	July 12	Sept		May 31	1.	July 26	P M.- -	—	Sept 26	5	Dec. 4	P M.—		Aug. 4	.5	Nov. 18	P. M.—	
8½	Poppy	" 24	1	" 25	"	—	May 26	1.	May 27	"	- -	June 6	1	June 11	Sept.	—	June 20	5	July 24	P M —		" 4	.5	" 18	P. M.—	
9	Topsy.	Mar 16	2.	July 6	P. M.—	—	" 24	1	July 20	P. M --	—	July 3	.5	Nov 18	P. M —											
9½	Winsome Beauty	May 24	1	May 25	Sept.	—	" 26	1	May 27	Sept	—	May 30	1	July 19	" —	—	July 3	5	July 8	Sept		Sept 26	.5	Dec. 8	P. M.—	
10	Royal Lake Edward	June 6	1.	June 7	"	—	Sept. 26	.5	Nov 24	P M.—		Aug 4	5	Oct 12	P M —	—	June 20	1.	Oct. 12	P M —	—					
11	Euroma 4th.	April 13	2	July 6	P. M.—	—	Mar. 10	2	July 6	" —	—															
12	Houston	Mar 10	3.	" 6	" —	—	April 13	2	" 6	" —	—															
13	Hellen.						Mar. 13	2	" 6	" —	—						April 12	2	July 6	P M —	—					
5	Dairy A.	April 20	2.	" 6	P M.—	-																				
5½	Dairy B.	" 20	2.	" 6	" —	—																		July 3	.5	Sept. 21	Septico-pyemia
6½	Hawthorne II.	—	—	—	—	—	May 26	1.	July 30	P. M.—	—	June 30	5	Nov 18	P M —		April 4	.5	Nov 18	P M.—						
5½	Dairy B.	May 24	1.	May 26	No.P.M.	—	May 31	1	Oct. 12	P M —																
8½	Poppy	Sept. 26	.5	Dec 8																						
0	Rose H..	Nov. 25	.5	" 16	Pneumonia																					
9½	Winsome Beauty	Aug. 4	.5	Oct. 12	P. M.—																					

Key to Table: —No Tuberculosis. †-Tuberculosis slight. ††-Moderate. †††-Extensive. G. P.—Guinea Pig. Sept.—Septicemia.

Animal's Number	G. P. Inoculation		Death		Microscope	G. P. Inoculation		Death		Microscope	G. P. Inoculation		Death		Microscope	G. P. Inoculation		Death	
	Date	Dose	Date	Cause		Date	Dose	Date	Cause		Date	Dose	Date	Cause		Date	Dose	Date	Cause
	1905	C. C.	1905			1906	C. C.	1906			1906	C. C.	1906			1906	C. C		
27	Nov. 24	.5	Dec. 15	P. M.—		Feb. 12	.5	June 7	P. M.—		April 28	.5	July 9	No P.M.		Aug. 16	.5	Nov. 14	P. M.–
28	" 24	.5	" 14	Sept.		" "	"	" "	" "		" "	"	April 8	P. M.—					
29	" 24	.5	1905 Dec. 21	P. M.—		" "	"	June "	" "		" "	"	July 24	" —					
30	" "	.5	" 22	" "		" "	"	April 26	Pneumonia		April 28	.5	April 29	Sept.		" 16	"	" "	" "
31	" "	.5	" 3	Sept.		" "	"	June 7	P. M.—		" "	"	" "	"		" "	"	" "	" "
32	" "	.5	1906 Jan. 3	P. M.—		" "	"	" "	" "		" "	"	" "	"					
33	" "	.5	1905 Dec. 3	Sept.		" "					" "	"	" "	"					
34	" "	.5	" 5	"							" "	"	" 8	P. M.–		" "	"	Aug. 18	Sept.
35	" "	.5	" 2	"		Feb. 12	.5	June 7	P. M.—		April 28	.5	April 30	Sept.		" "	"	Nov. 14	P. M.–
36	" "	.5	" 18	P M.—		" "	"	April 18	Pericarditis		" "	"	" 8	P. M.—					
37						" "	"	May 1	P. M.—		April 28	.5	May 3	Sept.		" "	"	Sept. 4	" "
38	Nov. 24	.5	Dec. 6	Sept.		" "	"	June 7	" "							" "	"	Nov. 16	" "
39	" "	.5	" 23	P. M.—		" "	"	May 26	Pneumonia		April 28	.5	May 1	Sept.					
40	" "	.5	" 22	" "		" "	"	" 2	Internal Hæmorrhage		" "	"	" "	"					
41	" "	.5	" 8	Sept.		" "	"	June 7	P. M.—		" "	"	" 2	"		" "	"	Aug. 18	Sept.
42	" "	.5	" 13	P. M.—		" "	"	" "	" "		" "	"	" 1	"		" "	"	Nov. 14	P.M.–
43	" "	.5	" 1	Sept.		" "	"	May 18	Pneumonia		" "	"	April 29	"		" "	"	" "	" "
44	" "	.5	" 21	P. M.—							" "	"	April 8	P. M.—		" "	"	" "	" "
45	" "	.5	" 25	" "		Feb. 12	.5	June 7	P. M.—		April 28	.5	April 30	Sept.					
46	" "	.5	" 27	" "		" "	"	" "	" "		" "	"	" 8	P. M.—					
47	" "	.5	1906 Jan. 27								" "	"	" "	" "					
48	" "	.5	1905 Dec. 12	P. M.—		Feb. 12	.5	June 7	P. M.—		April 28	.5	May 6	Sept.		" "	"	" "	" "
49																			
50						Feb. 12	.5	May 29	Pneumonia										

in all cases they died with septicaemia. We then decided to reduce the size of the dose, and it was not until we had reduced it to .5 c. c. that we succeeded in getting a reasonable number of guinea pigs to live. Occasionally small lesions that somewhat resembled tuberculosis were found present in guinea pigs that were killed for post mortem purposes or that died. When these conditions were encountered other guinea pigs were inoculated from the suspected tissue or pieces were fixed, inbedded, cut, and stained to see if tubercle bacilli could not be demonstrated.

A study of the above table shows that one animal, Rosella No. 2½ (2.08%), was found to pass manure that contained virulent tubercle bacilli. It is to be observed also that this animal did not pass such bacilli in large enough number that they could be found by microscopical examination, although they were present in sufficient abundance to produce tuberculosis in the experimental animals by inoculation.

Nov. 8, 1905, this cow, No. 2½, was killed (see Autopsy Records, page 53) and guinea pigs were inoculated from the filtrate obtained by mixing 5 c. c. of water with 1. gram of the contents of the paunch, small intestine, and rectum. The guinea pigs inoculated from intestinal and rectal material filtrates died in a short time from septicaemia, and hence gave no evidence in the matter of tuberculosis. The one inoculated from the paunch contents lived for about two weeks. Upon examination post mortem many small apparently caseous areas were found present in the liver. A guinea pig was inoculated from small pieces of the liver of this animal, but unfortunately died before it was time for tuberculous lesions to develop. From the lesions found in the original guinea pig inoculated from the paunch contents it was quite evident that it was affected with tuberculosis.

As will be observed upon reading the post mortem notes on this case (No. 2½) no intestinal ulcers were found. It seems quite safe to assume that the tubercle bacilli present in the manure came from the lungs by way of the gullet. Attention should be called to the fact that the lungs were badly affected containing abscess cavities. These cavities might easily furnish bacilli in enormous numbers to infect the paunch contents, which were proven virulent.

AUTOPSY RECORDS.

It should be said in explanation of the following meagre records, that the cattle were killed by Swift & Co., at South St. Paul, Oct. 31, 1905, under federal inspection, and that the killing was done so rapidly that there was scant opportunity for examination post mortem.

Hawthorn II. The Lungs, bronchial, and mediastinal lymph glands were badly affected with tuberculosis.

Gipsy Girl. The posterior lobe of the right lung was moderately involved.

Black Bess. The submaxillary lymph glands contained a considerable quantity of pus. The left lung was also slightly involved, and nearly all the thoracic lymph glands showed involved areas. The intestinal lymph glands were normal.

Poppy. Both lungs showed areas that contained cheesy pus. These areas were quite uniformly distributed throughout both lungs.

Bonnie Wild Rose. Both lungs were slightly affected. The mediastinal and bronchial glands were also involved.

Mine Drop VIII. No post mortem notes obtained.

Rosella, No. 2½. Aged Angus cow in prime condition, killed Nov. 8, 1905. (See Figs. 1, 2, 3, 4, 5.) The udder and supermammary glands are found to be unaffected. The superficial inguinal lymph glands are enlarged and contain many miliary tubercles, some of which are partly calcified.

The omentum is thickly studded with tubercles varying in size from that of a millet seed to that of a small chestnut. (See Fig. 2.) Along the line of attachment of the great omentum to the paunch there is a large mass of grape-like tubercles which is from 3 to 7 inches broad. and extends along the attachment for about 3 feet. A few small tubercles are present on the peritoneum covering the fat around the rectum and kidneys.

A large number of tubercles are noticed on the peritoneal surface of the liver. Upon cut surface, the liver tissue is found to be normal with the exception of an abscess about the size of a walnut in the apex of the left lobe. This abscess contains a small amount of thick pus encapsulated by a thick fibrous wall. The peritoneum covering the spleen contains many tubercles but the spleen

Figure 1.—ROSELLA, Animal No. 2½.
This animal passed virulent manure and also virulent nasal secretion.

tissue appears normal upon cut section. No ulcers of the intestinal mucosa are found upon a very careful examination of the entire intestine. Two glands in the colic mesentery are studded with miliary tubercles and one lymph gland near the ileocecal alve contains caseated areas. The kidneys are normal in appearance on the surface and upon the cut section. A few tubercles about the size of a small pea are scattered over the surface of the bladder and also over the peritoneal surface of the uterus. Several small grayish white nodules, which contain pus are observed in the mucosa of the horns and body of the uterus.

The right ovary contained an elongated cavity about 1¼ inches in length and ½ inch in diameter, filled with thin pus. Several small calcified tubercles are also observed.

The diaphragm is very thickly sprinkled with flattened tubercles from 1 mm. to 2 cm. in diameter.

One of the posterior mediastinal lymph glands is enlarged to about the size of a man's fist. Upon cut section

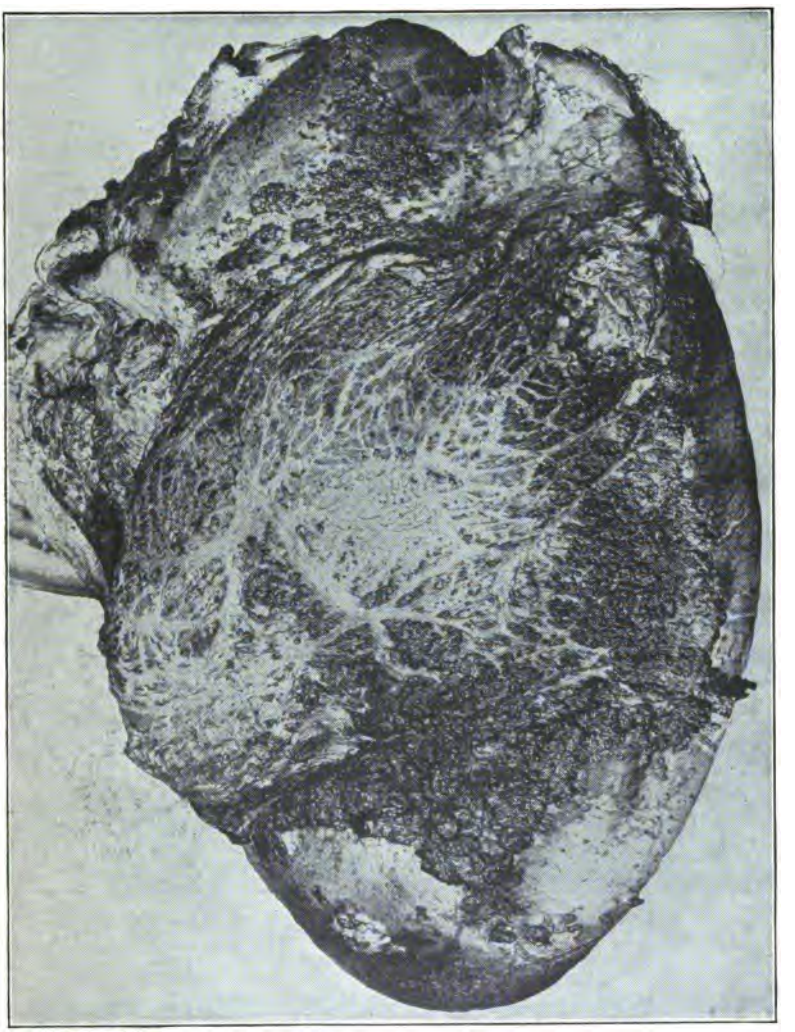


Figure 2.—PAUNCH AND OMENTUM OF THE COW, ROSELLA.
Note the extensive involvement. These tubercles vary in size from that of a millet seed to large masses.

it reveals a broken down caseous center which grates when cut. Two of the bronchial glands are enlarged to about the size of turkey's egg. Upon cut section they show a broken down caseous center which contains calcified granules. Glands around the supernumerary bronchus are not affected.

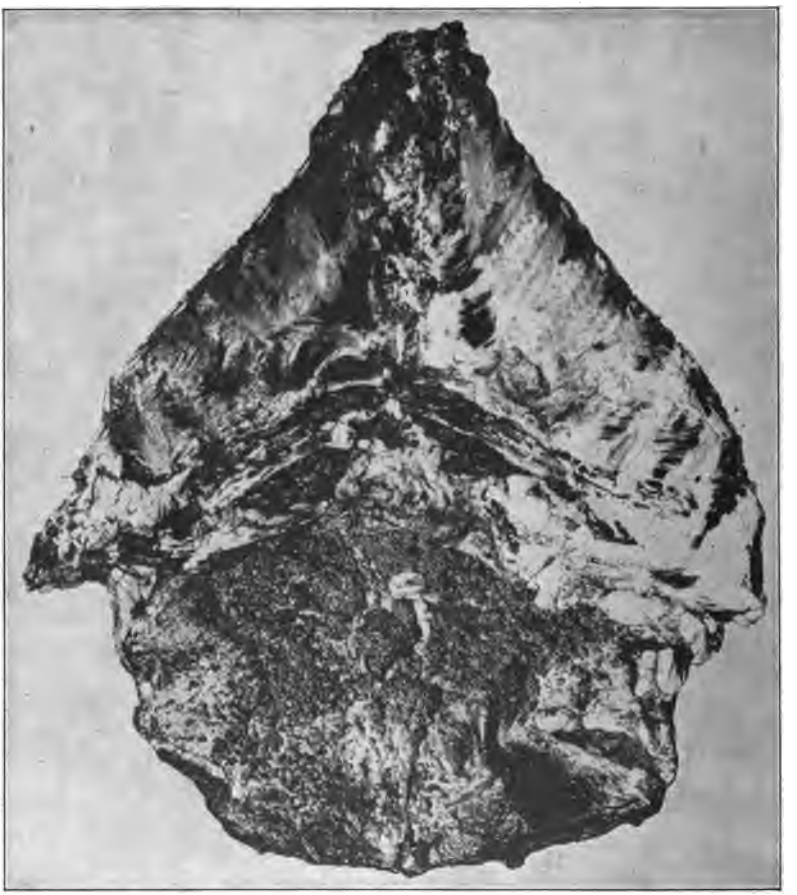


Figure 3.—Bottom of Chest and Abdomen of Rosella.
Note masses of tubercles in the latter cavity. The short sections of the ribs will enable the reader to locate these parts.

Both lungs contain many abscesses varying in size from that of a chestnut to that of an egg. Some of these contain thick, viscid pus, while others were caseous and partly calcified.

Both retro-pharyngeal lymph glands contain caseous areas.

Submaxillary lymph glands are normal.

The peritoneal lining of the abdominal wall is thickly studded with tubercles, particularly on the left side and the floor. (See Fig. 4.)

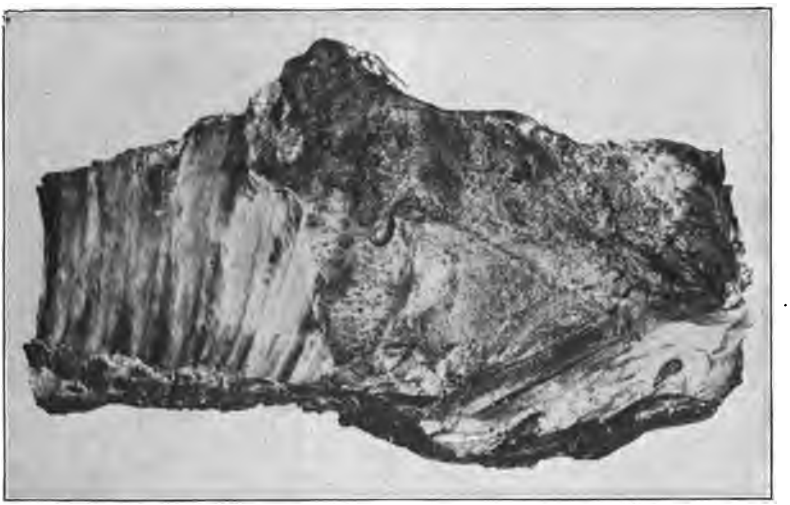


Figure 4.—Section from the Chest and Abdominal Wall of Rosella Showing Extensive Disease.

Hawthorne I. No. 3. Aged grade shorthorn ,calved March 14, 1905. Did well until March 18, when a slight swelling of entire udder was noticed. The cow was first examined March 19, with following result: Temperature 107, pulse rapid, respiration rapid and shallow. Posterior half of udder much swollen and hard.

Diagnosis, Garget. Temperature remained at 107 for several days and then dropped to 103. Bowels loose, udder hard, no improvement. March 23, a thin, dark, bloody discharge from right hind teat. Died during the forenoon of March 24.

Autopsy, March 24, 1905.

Autopsy.—Upon opening the thoracic cavity, the mediastinum was found covered with tubercles varying in size from that of a millet seed to that of a pea. The cephalic lobe of the right lung was badly affected. The left costal and viceral pleurae contained many miliary tubercles. The diaphagmatic pleura also showed many small tubercles.

The liver tissue was of a brownish yellow color. This was probably due to bile infiltration as other tissues exhibited a similar color. The gall bladder was very much enlarged, and contained about two quarts of greenish yellow bile. The spleen pulp was very soft, and of an almost

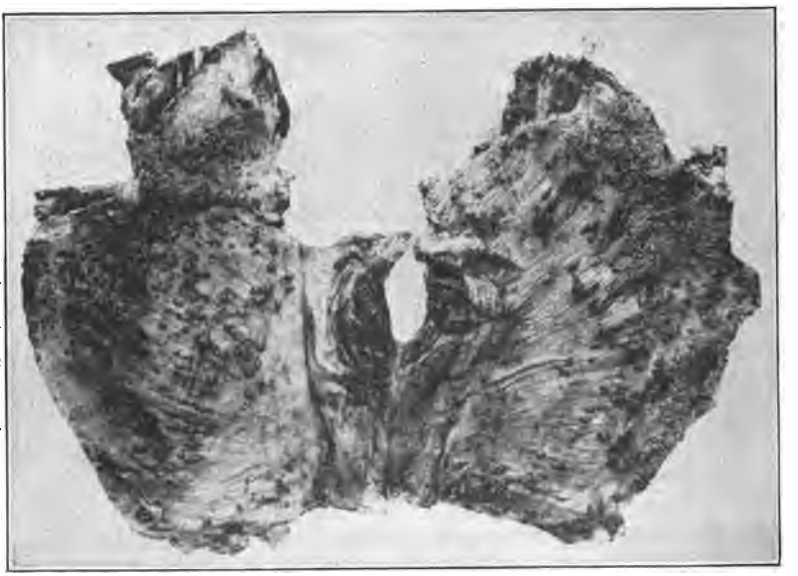


Figure 5.—Diaphragm of Rosella.
Note tubercles.

semi-liquid consistency. The stomach and intestines were apparently normal.

Winsome Beauty. Autopsy Nov. 3, 1906. Aged shorthorn. The intestines were badly decomposed as the animal had been dead for about 36 hours and it was therefore thought unwise to cut them open and make examination for ulcers. The intestinal lymph glands were all normal in appearance. The liver and stomach were also apparently normal. Both kidneys were very friable, and the parenchyma contained many gas bubbles. The left pleural side of the diaphragm, the costal, and visceral pleurae were thickly studded with tubercles varying in size from that of a No. 6 shot to that of a pea. The post mediastinal lymph glands were completely decomposed, but some caseous material was found in the vicinity of the posterior mediastinum, so it seems fair to suppose that they may have been tuberculous. There was also a very marked acute pleurisy on both sides of the cavity.

The parietal and visceral pericardia were adherent to each other. A small amount of effusion was also present in the pericardial sac.

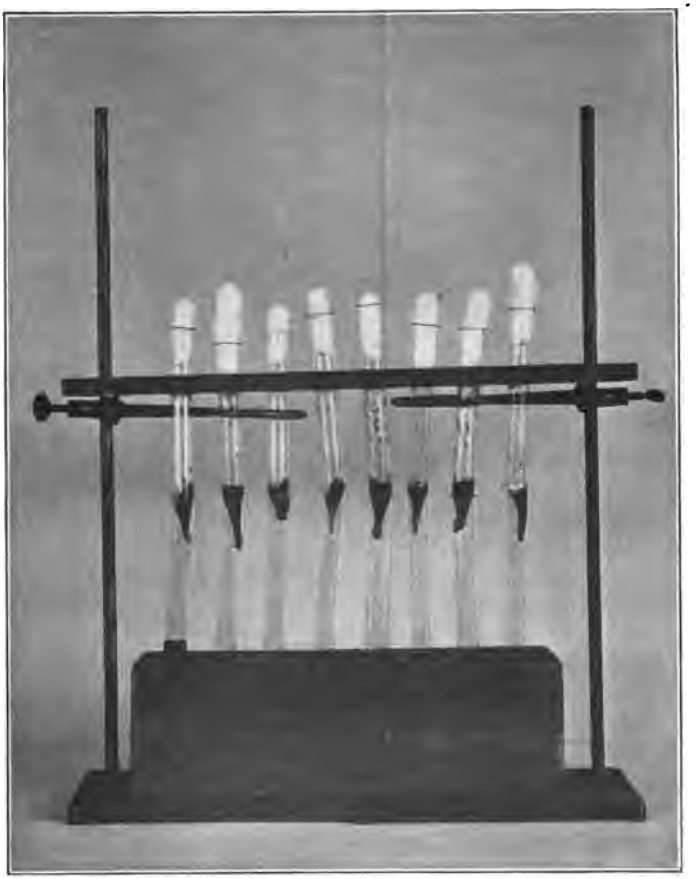


Figure 6.—Method of Filtering the Manure Suspension.

VIRULENCE OF NASAL SECRETION.

In view of our almost negative results in studying manure of tuberculous cattle as to virulence, only one cow being shown to pass virulent manure out of 45 cows examined, the question arose how then were these remaining 44 cows passing off tubercle bacilli, if at all? Coughing was not conspicuous in either herd, and yet here were 45 tuberculous cows, some of which, judging from common experience, must have been excreting virulent tubercle bacilli. It is a matter of common observation that given tuberculous cattle confined in stable with others, a large number

Figure 7.—Rectal Spoon.

of mature animals may become infected during a single winter, and it has been shown that outdoor transference of infection is not by any means impossible.

In view of these considerations it seemed probable that there must be some other method by which tuberculous cattle commonly pass off the bacilli of tuberculosis aside from coughing and in milk. We therefore decided to undertake a study of the nasal secretion. This seemed a quite plausible source of infection in view of the very common habit which cows have of licking their feed boxes, mangers, and each other's faces.

Tuberculous cattle were available at the university farm for this purpose, and the work was undertaken which is here briefly reported.

In conjunction with the work on manure, inoculations were also made from the nasal mucous secretion. Material was obtained in the following manner: Absorbent cotton was sterilized and small pieces of it were grasped with long sterilized forceps and pushed up into one of the nasal cavities of the animal for 2 or 3 inches, while its head was held by an assistant. Usually the animal would become very much excited and breathe rapidly and forcibly, which tended to expel adherent secretion so that usually a sufficient quantity of material would be obtained in this manner.

In most cases, material was obtained from both nostrils. The cotton was then removed from the forceps and placed in a sterile test tube. Five c. c. of water was poured into each tube. The tube was thoroughly shaken, and the cotton removed. Two c. c. of this suspension was injected subcutaneously into guinea pigs. The guinea pigs were allowed to live at least six weeks, and were then killed by chloroform, and examinations post mortem held.

Inoculations were made from the nasal mucous secretion once from each of the following animals, 14 in number:

Nos. 2½, 4, 4½, 5, 5½, 6, 6½, 7, 7½, 8, 8½, 9, 9½ and 13. Two inoculations were made from No. 2½ with positive results each time. All other inoculations were negative. This shows a very small percentage, only 6.6 %.

SUMMARY, AND COMPARISONS OF RESULTS.

It will be obsered that we have had 45 animals under experiment. Of these, we have tested for virulence the manure of 16 cattle three times; 1 cow 5 times; 2 cows 4 times. The feces of 14 animals were tested for virulence 2 times, and 7 animals were tested for virulence once. Of the entire lot but one, Rosella, of Glendale, feces experiment 2½, gave virulent manure, and it is intesesting to note that in this case the nasal secretion was uniformly virulent also.

Nasal secretion of 14 cattle was tested for virulence, and but one, the same cow which gave virulent feces, was found to give a virulent nasal secretion. This seems somewhat remarkable in view of the considerable number of tuberculin reacting cattle whose manure and nasal secretion were examined in our work, and the apparently conflicting results obtained by others quoted.

The results obtained by Schroeder and Mohler[1] and Schroeder and Cotton[2], see page 46, seem to differ very radically from results which we have obtained in similar work. There does not appear to be any features in the reported work to account for such radical differences. Either our cattle were remarkably free from lesions which would result in contamination of the manure, or Schroeder and Mohler, and Schroeder and Cotton experimented with animals in which such lesions were quite common. These experimenters found that a large proportion of their seven experimental animals gave virulent manure and none of them virulent nasal secretion.

The manure of 45 tubercular cattle was tested for virulent bacilli by the methods described. One animal (2.08%) gave positive results. Nasal secretion of 14 was tested for virulence as described in previous pages. One of these (6.6%) gave positive results, this being the same cow which gave virulent manure.

Schroeder and Cotton[2] found tubercle bacilli by microscopic examination in the manure of 5 of 7 tubercular

cattle. Of these 5, three cattle passed manure which was proven virulent by inoculation.

In view of our widely differing results, it is highly important that more work be done along this line for it is a serious problem.

It is evident that virulent bacilli may pass through the entire alimentary canal and remain virulent. In the one case where we found a cow passing virulent manure, we also found virulent bacilli in the paunch. This has been even more positively shown in the work of Schroeder and Mohler[1] and Schroeder and Cotton[2].

If a considerable percentage of tuberculous cattle are passing virulent bacilli in the manure, then this method of dissemination is a serious one for both bovine and human.

If but few cows pass virulent manure, it is important to remember that those few are dangerous and seriously objectionable factors in any herd.

Until further information is available, and considering the disastrous results which have been shown to be possible from virulent manure, it becomes evident that tuberculin reacting cattle should not be allowed to remain in any stable from which milk is taken for food purposes or where they are associated with healthy cattle, even though the milk of the reacting cows be discarded.

Microscopic test for the presence of tubercle bacilli in manure is not reliable. We were unable to demonstrate them in the case of cow No. 2½ though this cow was passing virulent manure. Nor does it appear feasible at present to differentiate by microscopic examination between the bacilli of Johne's disease, or other acid-fast bacilli resembling tubercle bacilli, and virulent bovine tubercle bacilli.

The method of inoculation by injection of filtrate from a suspension of manure is fairly satisfactory as described. Five-tenths c. c. (.5 c. c.) of such filtrate appears to be approximately the maximum dose which it is practicable to use on account of the development of septicaemia in the inoculated animals.

SUMMARY.

(1) **"Hogging off corn" may be practiced with profit on many Minnesota farms.**

(2) **Pork was produced with less grain by hogging corn than by feeding** ear or snapped corn in yards. (See page 76.)

(3) **Hogs fed in field gained nearly one-third more rapidly than those** fed in yards. (See page 81.)

(4) **The cost of fencing corn fields may be from $1.00 to $2.50 less** per acre than the cost of husking the corn. (See pages 89-95.)

(5) The stover lost in following this method is, in many cases not worth the cost of saving it. (See page 86.)

(6) **Good pastures are in most cases necessary for the economical production of pork.** (See page 87.)

(7) **To have good hog pastures and to hog off corn economically, a carefully worked out plan with a view to economy of labor** and fencing is essential. (See pages 95-97.)

(8) **A four year rotation (grain, clover, corn, corn,) works very satisfactorily on small fields, for hogs, as it gives twice as much** corn as pasture, which is about the proportion used. (See pages 96-97.)

(9) **A three year rotation of larger fields is practical when sheep are** at hand to make use of the extra pasture. (See page 101.)

(10) **Any fields permanently fenced for hogs should be convenient to the farmstead, as large as can be used by this class of stock,** and of such shape as to reduce to a minimum the amount of fencing necessary to enclose an acre of land. (See page 95.)

(11) It requires no more labor to prepare for subsequent crops fields that have been hogged off than those that have been treated by the ordinary methods of harvesting. (See pages 84-85.)

(12) Hogs waste no more corn in field than when fed in yard. They pick the corn as clean as most men do in husking. (See pages 78-84.)

(13) Three pounds of rape, costing 15c, sown in corn at last cultivation, furnishes considerable succulent feed, which may take the place of high priced shorts. (See page 70.)

(14) Labor in caring for hogs is not increased by hogging corn, but may be decreased, if systematic methods are employed.

(15) It is not expected that all corn raised be fed off with hogs, but the amount they can clean up from the time it is nicely glazed until the weather becomes unfavorable, (two or three months in Minnesota), may be very economically fed in this way.

(16) Hogs should not, as a rule, be turned into more corn at one time than they can eat up clean in two or three weeks. The shorter period is preferable.

Reprint of Bulletin No. 104 of this Station.

PORK PRODUCTION.

HOGGING OFF CORN *VS.* YARD FEEDING.

D. A. GAUMNITZ, A. D. WILSON, L. B. BASSETT.

Profit in pork production depends largely on the economy exercised in the growing and fattening of pigs. The cheapest gains are made in the fattening process when the pigs have been so grown from birth that they respond readily to the food given later; when they are kept comfortable and healthy; and when the proper nutrients are supplied them at a minimum cost.

As a general proposition, barley or corn with suitable adjuncts furnishes the cheapest fattening foods. In the southern two-thirds of the state, corn is usually the cheaper feed, while in the northern section barley is generally the more economical for pork making. Market prices for grains are, however, the governing factors.

As a method of economical feeding the practice of "hogging off" corn has been growing in favor during the past few years, and seems to be a practical and economical way of feeding hogs several weeks during the fall.

This bulletin reports the results of two years' work at the Minnesota Experiment Station, in comparing this with other methods of feeding corn; also the results obtained by several farmers who have practiced hogging off corn for one or more years.

HOGGING OFF CORN—WHAT IT MEANS.

Hogging off corn is, comparatively a new phrase. It means in farm practice, turning the hogs into a field of standing corn, allowing them to pull down the stalks and consume the corn at will.

This practice was not uncommon twenty or twenty-five years ago in Ohio. It was not followed extensively because it appeared to be a shiftless, untidy way of har-

Fig. 1.—Field of corn ready for the hogs in 1905. The crop of rape cost from 15c to 25c as it stands. It takes the place of weeds and is an important adjunct to the corn

vesting corn, and it was not believed that the hogs made as good gains as when yard fed or closely confined.

These ideas combined with a plea by agricultural scientists for better farming, which was supposed to mean cutting and carefully husking the corn, led many to discontinue the practice.

About the time this system of hogging corn was discarded in the East, the western farmers took it up, especially in Illinois, Iowa, Kansas, Nebraska and Oklahoma. Some have followed it more or less since that time with good results.

Corn is a comparatively cheap feed in the Central Western states. An acre of corn can be grown up to harvest for from $4.00 to $5.00, and with rental of land added, for about $7.50 to $8.50. (See bulletin 97, Minnesota Experiment Station.) With fair yields, the cost per bushel is very low. High prices for labor, together with low prices for corn warrant economy in labor even though it may lead to a slight waste of corn.

The idea that hogging off corn is a shiftless way of farming is based neither on facts nor good judgment. So far as the farmer is concerned, the method that yields the largest net profit and the greatest possibility of enjoyment for himself and family is the best to follow. When it is learned that corn may be economically harvested with live stock and that good timothy and clover hay can be produced as cheaply per ton as corn stover can be saved this idea will change.

Questions Pertaining to Hogging off Corn.

Those who have not tried hogging corn raise a great many questions as to its practicability, and it was for the purpose of getting facts with which to answer these questions that the experiments in hogging corn at the Minnesota Experiment Station were undertaken. These questions are:

1. Is not a larger amount of corn wasted? See page 78 and 84.
2. Do hogs fatten well with so much run? See page 77 and 78.
3. Does it not cost more to fence than to husk and feed the corn? See page 102.
4. Is not a large amount of the value of the crop lost by not saving the stover? See page 86.
5. Are the fields not left in poor condition for the following corn? See page 84.
6. Is it not expensive to care for hogs when away from the buildings? See page 82 and 105.
7. How large should hogs be when turned in the cornfield? See page 104.
8. How long is the season during which hogs may be in the cornfield? See page 82 and 104.
9. On how large an area should hogs be turned at one time? See page 106.
10. What kind of corn is best for hogging off See page 104.
11. How rapidly will hogs gain? See page 81.

DETAILS OF THE EXPERIMENT.

The Division of Agriculture is devoting three 3-acre fields to a three year rotation of corn, barley and mangels, for the purpose of determining a practical method by

which the cost per acre of growing mangels may be reduced. This gives one field (8x60 rds.) of corn each year and on this field the hogging corn experiments have been conducted. The corn grown was Minn. No. 13, planted in check rows on well prepared soil. It was cultivated four times in 1905 and five times in 1906. Three pounds of rape were sown broadcast before the last cultivation which was July 15th, 1905, and July 20th, 1906.

The lots that were used for the yard fed hogs were about 40 feet wide and from 60 to 75 feet in length.

Fig. 2.—One way to get around the labor problem. These huskers are hard at work but contented.

Beginning of the Experiment and Nature of the Pigs.

It was intended to turn the pigs into the cornfield as soon as the corn dented. In 1905 pigs could not be secured early, and in 1906 the corn was difficult to husk by hand early, for the yard pigs, so it was thought best not to start the work until Sept. 19th. Ordinarily hogs should be turned into the corn by Sept. 1st.

Through Mr. McKissick and Mr. Young, managers of North Oaks Farm, near St. Paul, 38 Grade Berkshire pigs of late winter and early spring farrow were secured

for the work in 1905. One pig was taken from the college herd to make up the number desired for the experiment. Being late in the season, it was decided to put two-thirds of the pigs into the cornfield so as to harvest the crop, if possible, before snow covered the corn. One-third of the pigs were fed in the yard. They were divided equally as to quality and weight, the 26 pigs averaging 148 pounds, and the 13, 147 pounds.

In 1906 another lot of spring farrowed pigs were secured from North Oaks Farm. These with some crossbreds of the same age raised on University Farm were started on the experiment Sept. 19th. The pigs were divided according to quality but in weight some allowance was made, because in 1905 the field pigs had gained so much more rapidly than the yard pigs. This year the field lot averaged 112.6 pounds and the snapped and ear corn lot 137.5 pounds. In 1905 the field pigs took to the hogging down of corn rather rapidly, learning to do it in about three days, but in 1906 it required about a week or ten days for the 112 pound pigs to learn how to break down the corn and find the ears, though they ate the rape and lower leaves of the corn with relish.

Sampling and Shrinkage of Corn.

To make a comparison of the different methods of feeding it was necessary to know the amounts of feed consumed. In 1905 the amount of corn fed in the yard was easily determined when husked and hauled, but that in the field had to be estimated after sampling. Out of every acre, which contained 88 rows 8 rods long, two rows of corn were husked and weighed. This gave a very fair basis for determining the amount of corn in the field. In order that both the field and yard hogs might have corn of the same kind and in the same condition, a proportionate amount of the same variety of corn was husked at the same time from an adjoining field for the yard hogs. Each time the field hogs were turned into a new piece of corn, a new supply of the same kind was secured for the yard hogs.

In 1906 two lots of pigs were fed in yards, one on ear corn and one on snapped corn or corn which included both the ear and the husk instead of the ear alone as in ear corn. Snapped corn is more easily and quickly gath-

ered than when husked and is also very representative of shock corn, of which much is fed. The samples this year were taken in the same way as in 1905 except that the weighed samples taken from the fields as well as the samples which were taken from the loads gathered for the yard lots were preserved until the 29th of December and then weighed to determine the amount of shrinkage in weight. This made it possible to reduce the amount of corn used to a marketable basis. The corn for the yard lots was all snapped. Then one load of the snapped corn was husked for the lot fed on ear corn and the corn and husks weighed. The weights furnished a basis for approximating the amount of corn eaten by the lot fed on snapped corn, and of estimating the amount eaten by all the lots on a market basis.

It was found that:

Corn husked Sept. 20th shrank 21.5% in 101 days.

Corn husked Oct. 10th shrank 11% in 81 days.

Corn husked Oct. 27th shrank 4% in 64 days.

and that in the early part of the season the husks represented 11 % of the total weight of ear corn and 100 days later 6 % of the total weight of the ear corn—a shrinkage of 5 %.

Feeds and Adjuncts.

Both the yard lots and the field lots were fed shorts to supplement the corn and provide a better ration for growth. One pound of shorts a day per hundred pounds of pig was the amount fed. The pigs were weighed weekly and the amount of shorts fed corrected upon the basis of the increased weight. The field hogs had access to corn at all times. The yard hogs were given all they would eat up clean twice a day. Salt was kept before them constantly and water was given in such amounts as they demanded. Each lot of hogs was watered and fed shorts twice each day. The yard hogs also seemed anxious for their allowance of shorts. In the early portion of the season, while rape was green and the lower corn leaves succulent the field hogs showed no great desire for the shorts. It is doubtful, therefore, whether it is necessary to feed so much shorts when green feeds are available.

Fig. 3.—A field where corn has been hogged off.

Photograph showing on the left a portion of a corn field that has been hogged off. On the right may be seen the standing corn before the hogs are turned in.

FENCING.

At the time of hogging off the corn the field was fenced with a 26″ ribbon of woven wire made of 7 strands with stays every 12″. A barb wire was used near the ground the first year and a barb wire above the ribbon the second year. The woven wire was fastened with three staples at a post and close to the ground. The corner posts were well set and braced. Line posts were set two rods apart. This fence proved entirely satisfactory and retained the pigs perfectly. It may be stated further that in 1905 some very wild pigs were used, they having been grown in the woods and on pastures some distance from buildings. These pigs were capable of breaking down, burrowing under, or jumping over this rather modest fence, if so inclined, yet they did not do it.

In all cases the pigs were given but an acre of corn to hog off at a time. Wooden hurdles were used to separate it from the remaining field because they were on hand

and convenient. The pigs did considerable shallow rooting and examination revealed the fact that they were seeking angleworms. Whether these worms were of much value as food or as a tonic cannot be said, but the pigs in the field appeared sleeker and heartier than did the yard lots.

SHELTER.

In 1905 neither the yard nor the field lot of hogs received any protection other than a straw bed in the early part of the experiment. Both were given enough straw so that they could lie upon it without bunching and so that their bodies did not come in contact with the ground. As rainy and snowy weather came on, it was found that without shelter the hogs were inclined to pile considerably as soon as their beds became wet. This, of course, is objectionable, as pigs are likely to become heated and then take cold easily. The pigs in the field seemed to suffer less from colds than those in the yards and were affected less by rain and snow storms.

TABLE VII.—Showing Grain Required to Produce 1 pound of Gain.

Year	Date Exp. Began	Date Exp. Closed	No. of pigs in experim't	Grain Consumed for 1 lb. of gain Produced		Total lbs of Feed Eaten for 1 lb. Gain
				Shorts	Ear corn	
		Lot Hogging Corn			In Field	
1905	Oct. 11.....	Nov. 29.....	26	1.39	6.96	8.35
1906	Sept. 19...	Nov. 9.....	32	1.03	5.32	6 35
	Averages.....			1 21	6.14	7.35
		Lot fed Snapped Corn			In Yard	
1906	Sept. 19...	Nov. 9.....	8	1.43	5.01	6.44
		Lot fed 'Bar Corn			In Yard	
1905	Oct. 11.....	Nov. 29.....	18	1.69	8.31	10.42
1906	Sept. 19...	Nov. 9.....	8	1.46	5.73	6.77
	Averages.....			1.57	7.02	8.59

In 1906 the yard lots were given shelter and dry straw beds. The field hogs were treated just the same as in 1905, viz., given straw upon which to sleep.

Results of Experiments.

Table No. VII shows the amount of grain consumed per pound of gain produced. The weight of the corn in 1905 is the green weight as husked after October 11th. The corn in 1906 in every case was shrunk until December 29th, or the first of the year (see page 73), so as to get it on a marketable basis.

According to this table the cost of pork production appears high in 1905. This is partly due to the fact that the weight of green corn was used. If shrunk to a marketable basis as at January 1st, from 15% to 20% shrinkage would have to be made. Then, too, feeding the swine so late in the year without shelter, the period extending into a snowstorm and intensely cold weather, did not produce gains as economically as would have been the case earlier in the season under more favorable conditions.

Fig. 4.—Field lot of hogs a week after the beginning of experiment in 1906.

Gains in Field Lot and Ear Corn Lot Compared.

The field lot of hogs produced pork for much less feed than did the hogs fed on ear corn. Averages for 1905 and 1906 show that 1.24 pounds less of feed (corn and shorts) were required to produce a pound of gain when corn was hogged off. Of this amount .36 pounds were shorts and .88 pounds were corn. The extra requirement of about .36 pounds of shorts amounts to a great deal to the farmer who has to pay $20.00 per ton for this feed, and

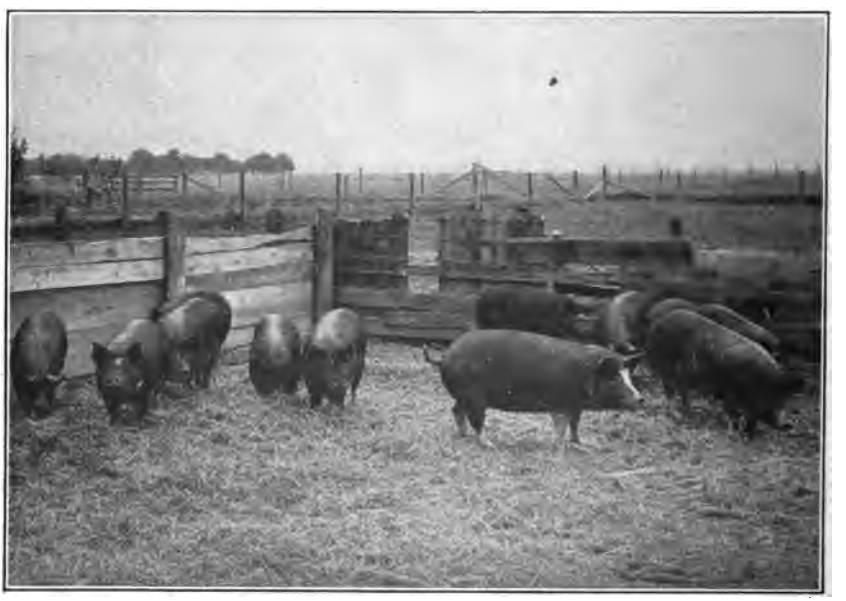


Fig. 5.—Yard lot of hogs one week after beginning of experiment in 1905

even then cannot get it regularly. At prevailing prices of feed, the extra amount of shorts and corn required for every pound of gain produced would cost at least from .80 to .90 of a cent per pound.

Why hogs do better in the field and make gains more economically is difficult to explain. The mineral matter and worms obtained from the soil and freedom to exercise and eat at will probably have a good effect upon digestion. Then, too, the ears of corn when husked become dry and hard, while those in the husk remain moist. Mastication

in the case of the moist corn is easier; the hogs eat more and therefore gain more rapidly and economically.

Field Lot, Ear Corn and Snapped Corn Lots.

But one year's work has been carried on with a view to comparing the gains made by the field lot and the snapped corn lot. This work was begun to determine the wisdom of feeding shock corn to pigs. Table VI shows that there is very little difference in cost of production between the field corn lot and the snapped corn lot, the

Fig. 6.Field lot of hogs at close of experiment, Jan. 24, 1906.

main difference being that the field hogs consumed .31 pounds more corn and the yard lots .40 pounds more shorts. A small difference, of course, is in favor of the field lot, because shorts is more expensive than corn. More work will need to be done along this line before the relationship between these two systems can be conclusively established.

The difference in grain consumed for pound of gain by the ear corn and the snapped corn lots in 1906 was more

perceptible, it being .33 pounds more (and this largely corn) in case of the ear corn lot. The amount of shorts consumed by the two lots being practically constant, and that of the corn variable, would indicate that unhusked corn which contains a higher per cent of moisture than husked corn is more effective.

Another deduction that might be drawn from the fact that both yard lots ate about the same amount of shorts, to produce a pound of grain, and the field lot much less, is that the amount of shorts required by those hogs fed in fields in which green crops grow would always be less than that required by hogs that were yard fed.

Effect of Feeding in Field Upon Subsequent Gain.

Those who feed swine in open ranges are loud in their praises of the splendid condition it puts animals in for future feeding. To determine positively just what the effect would be on hogs fed in the tests through extremely cold weather in 1905 the work was continued until Jan. 24th, the feed given the two lots being similar. Table VIII shows tabulated results.

TABLE VIII.—Showing Average Gains and Cost of Producing One Pound of Gain in Studying the Effect of Previous Management upon Pork Production.

	Average weight Nov. 29th.	Average weight Jan. 24th.	Average gain.	Feed required to produce one pound of gain.	
				Shorts.	Corn.
Field lot	213	260	47	4.41	10.02
Ear Corn lot	196	241	45	4.54	10.57

From this table it will be seen that the difference in amount of food required is small, altogether too small to constitute convincing proof, though the evidence is in favor of the field lot.

Amount and Rapidity of Gain.

The average weight at the beginning and at the close of the "hogging off" period are given for both 1905 and 1906 in Table IX.

TABLE IX.—Amount and Rapidity of Gain in Weight.

In 1905.

	Number of pigs in test.	Initial average weight.	Final average weight.	Total average gain.	Average daily gain.	Average daily gain in favor of field lot.	% more rapid gain in favor of field lot.
		Oct. 11	Nov. 29		Oct. 11 to Nov. 29		
Field lot	26	148	213	65	1.3		
Ear corn lot	13	147	196	49	.98	.32	32.6

In 1906.

	Number of pigs in test.	Initial average weight.	Final average weight.	Total average gain.	Average daily gain.	Average daily gain in favor of field lot.	% more rapid gain in favor of field lot.
		Sept. 19	Nov. 9		Sept. 19 to Nov. 9		
Field lot	32	112.5	188	75	1.44		
Snapped	8	137.5	196	58	1.11	.33	29.3
Ear corn	8	137.5	195	57	1.09	.35	31.5

Fig. 7.—Yard lot of hogs at close of experiment, Jan. 24, 1906.

It will be noted that each year greater gains were made by the field lot than by the ear corn lot. During a 50-day period in 1905 and a 52-day period in 1906, an average daily gain of 1.37 pounds was made by the field lot, 1.03 pounds by the lot fed ear corn and 1.11 pounds by the lot fed snapped corn. The lot fed snapped corn were fed during a 52-day period in 1906 only. Comparing the field and ear corn lots it will be noted that the former made an average of .34 pounds more gain daily. Expressed in per cent the field hogs gained 32.05 per cent more pounds or almost one-third faster than the ear corn fed hogs. To the farmer it means that the field hogs would gain in 75.2 days as much as the ear corn fed lot would gain in 100 days, or during the average hogging corn season of 66 days about 16 days less feeding would be required to give an equal finished weight. It means that the hogs may be placed upon the market 16 days earlier or if the owner were forced to sell on account of disease in the neighborhood, that he could sell to a somewhat better advantage because of the probable heavier weight of his hogs.

Fig. 8.—Corn field as left by the hogs.

Compared with the snapped corn lot, the field lot gained .26 pounds more daily. To make the same gain as the snapped corn lot made in 100 days, it would be necessary to feed the field lot but 81 days.

In order of daily average gain the lots rank as follows:

Lot fed in the field .....1.37 pounds
Lot fed snapped corn, ...1.11 pounds
Lot fed ear corn, ...1.03 pounds
In order of time required to make the same gain:
Field lot, ...100 days
Snapped corn lot, ...123 days
Ear corn lot, ...133 days

Marketing the Hogs.

Two weeks after the completion of the feeding test in 1905 it was decided to select an average group of hogs from each of the field and car lots to send to market at South St. Paul. The field hogs were somewhat heavier than the yard hogs, averaging 260 pounds as opposed to 241 pounds. They sold at $5.40 and $5.30 per cwt. respectively. These prices were supposed to be representative of the value of the two lots, but actual figures show that there was really not 10c per cwt. difference. If the field lot was worth $5.40 live weight, the carcasses were worth $6.91. On the same basis the yard lot should have sold for about $5.35 per cwt. instead of $5.30.

Table X shows there was a difference of .7 of 1% in the dressing of the hogs. This difference is due to the greater weight and fattening of the field lot of hogs. It has been found in slaughter tests at the School Meat Shop that the carcass yields are influenced by development and degree of fatness.

TABLE X.—Showing Yields and Sales—1905.

	No. of pigs sold.	Total live weight.	Average live weight.	Total dressed weight.	% yield dressed weight.	Price paid alive.	Actual selling price of 1 lb. dressed pork.
Field lot	19	4940	260	3860	78.1	5.40	6.91
Ear corn lot ..	11	2650	241	2050	77.4	5.30	6.84

Waste Corn in Muddy and Rainy Weather.

During the two years' work no more corn was wasted in the field than in the yards where ear and snapped corn was fed. When young pigs are first turned into a corn field they do not know how to find the corn, but soon learn that when a stalk is pulled down there is corn to be had. Several pigs will be after the same ear and very little is wasted. Later they become careless and do not eat up

Fig. 9.—A corn field that was hogged off in the fall, then disced twice and harrowed once the following spring

the corn so clean. If disturbed, they run away, the ear is left as well as the scattered kernels, and another stalk is pulled down. In a field without limitations, pigs are likely to waste more corn than in one so limited that they eat the corn off within 15 to 20 days. In muddy weather it is wise to limit the area so that all the corn would be eaten in from 10 to 15 days. Unless moldy, corn left on the ground for 15 or 20 days will be cleaned up by the hogs before they need to be taken from the field. Less corn was found in going over the three acres after it was hogged off than was found in going over a like area that had been

husked or snapped. Large and small ears, if sound, were gathered alike by the pigs. These little losses of moldy corn might be saved by turning brood sows or stock pigs into the field later, but it is doubtful whether the saving of it is wise.

Subsequent Condition of the Soil.

Pigs that have plenty to eat and a big range do not root holes in the soil as is generally believed. In no case was the soil left so uneven as to make extra work necessary in preparing the land for future crops. To get the land fitted for cropping two discings and one harrowing with the smoothing harrow is all the preparation given. Thus treated, the land yielded 46 bu. of barley per acre in 1906.

FIELD MANAGEMENT OF SWINE.

In producing pork of a given quality the problem of the farmer is to produce the maximum quantity at the minimum expense of feed and labor. Feed to the farmer really represents labor so that the economical production of the pork means necessarily the economical production of feed. Some of the farm feeds, such as corn, oats, etc., have a market value aside from their feed value. Such feeds, if fed, must be charged to the hogs or other live stock at market prices regardless of the cost of production. If the cost is greater than the market price the loss should be charged against the enterprise "grain" rather than to "live stock." There are, however, many kinds of feed on the farm which have no market value, as pasture, coarse roughage, etc.). Such feeds can be turned over to whatever class of live stock desired at the actual cost of production. Still other products may be brought to the stage where they may be utilized for feed, cheaper than they can be gotten into marketable condition (as corn or other crops fed off with live stock). In such cases the legitimate cost to charge against live stock for these feeds is simply the cost of producing them up to the stage where they can be utilized by the live stock.

TABLE XI.—Cost of Producing Corn. Ears Husked from Standing Stalks.

Northfield (Rice County), Minn.

Operation.	Total acreage 3 years.	Total cost.	Cost per acre.
Manuring*	602.68	$868.08	$ .576
Seed value	509.35	108.68	.213
Shelling seed	411.07	9.57	.023
Dragging	791.75	380.37	.480
Planting (horse planter)	670.83	150.73	.225
Plowing	605.89	730.28	1.205
Cultivating	776.74	1256.61	1.619
Husking on hill	331.32	1164.77	3.516
Machinery cost			.413
Land rental			3.500
Total			$11.770

* 40% of the cost of manuring is charged against the corn crop.

The above table taken from Minn. Bulletin No. 97 shows the total cost of growing a crop of corn and picking the corn ready for market, or for feeding. It will be observed that the average cost of picking this corn from the hill is $3.51. If instead of picking this corn, it had been fed off with hogs, the cost of fencing would have been from $1.50 to $2.50 per acre. This would mean a saving in the cost of harvesting of from $1.00 to $2.00 per acre.

It is not proposed that all of the corn on a farm be hogged off but a few acres conveniently arranged may be fed in this way to advantage. From Sept. 1st to Nov. 15th, hogs may be left in the fields and the labor of caring for them and picking corn will be saved, which is an item worthy of consideration.

Is It Economical to Save Corn Stover?

Any hay crop that is allowed to ripen before being cut is greatly reduced in feeding value. Corn stover or cornstalks on which a crop of corn has matured is likewise a very poor feed. It costs $11.77 to grow and save an acre of corn when the ears are husked from the standing stalks. It costs $14.745 to grow and save an acre of corn when it is cut and shredded. (See Minn Bulletin No. 97, pp. 41 and 42.) It is evident then, that to save an acre of corn stover, $2.97 worth of labor is required. An average yield

of corn stover at the Experiment Station is 1¼ tons per acre. Hence, it costs $2.37 per ton to save corn stover.

The cost per acre of producing timothy and clover hay (two cuttings) is $6.96. (See Minn. Bulletin No. 97, page 47.) A fair yield of such hay at two cuttings is two tons or more. This makes the cost per ton $3.48 or less.

The feeding value of a ton of stover is estimated by Prof. T. L. Haecker at $2.84, as compared with timothy hay at $6.00 per ton. Thus for every $1.00 expended in capital and labor for hay production, $1.72 worth of nutrients is secured and with the corn stover $1.19 worth of nutrients—a difference of 53c in favor of hay production.

Value of Pastures as Feed.

It is generally conceded that good pastures furnish by far the cheapest feed for growing animals on land not exceeding $100.00 per acre in value. The truth of this argument is quite evident when it is considered that the feed as obtained by the animal is in the very best condition. That is, it is succulent, contains all the nutrients in an easily digestible form and is obtained by the animal under very healthful conditions. In addition to this the cost of harvesting, curing, stacking and feeding is eliminated. On land worth $70.00 per acre a cow can be pastured for less than 5c. per day, while at the present price of grain and hay it costs on the average farm from 8c. to 12c. per day to feed the same cow in the barn.

Experiments show that as much pork can be made from one acre of good pasture as from one ton of shorts or corn. The cost of these feeds varies from $15.00 to $20.00 per ton. An acre of pasture will save, then, from $15.00 to $20.00 worth of feed. It is quite evident that in the economical production of animal products good pastures are an important factor.

The reason more and better hog pastures are not used is chiefly due to the fact that hog fences are quite expensive. The advent of the woven wire fence is overcoming this feature and now, land may be fenced hog tight at an annual cost of from $1.00 to $2.50 per acre, depending on the size and shape of fields fenced and cost of posts.

Kind of Pasture.

A permanent pasture for hogs, though being the cheaper to fence, is not entirely satisfactory for the more desirable crops, as clovers, (except white clover) cannot be kept in permanent pastures. The rooting of the hogs greatly reduces the returns and the pasture gets constantly poorer.

Sowing annual crops for pastures as peas and oats, rape, grain of any kind, or corn, is not wholly a success, owing to the great amount of labor required to plow, prepare and sow such pastures two or more times each year. The most satisfactory pasture for hogs is clover used but one year. The clover seed is sown with the grain crop the year before it is pastured, so there is no cost for plowing or preparing the land. Clover is readily eaten by pigs of all sizes and ages, and the first year it is seeded it gives as much pasturage per acre as any crop. The total cost of such pastures is represented by the following items:

Rent of land ($70.00 land at 5% interest	$3.50
Cost of 8lb of clover seed at 15c	1.20
Cost of fencing	1.80
Total	$6.50

If this acre of clover pasture is equivalent to ½ ton of shorts, it is returning a good profit. Many seasons it will return an equivalent of one ton of shorts, in which case there could be no question as to its value and profitableness.

Permanent Pasture.

As has been previously stated, permanent pastures for hogs are not as desirable as good clover pastures. In fact, they cannot be compared with them. Clover pastures are not permanent as most of the clover is killed out the first winter after it is pastured. Quite often wood lots or other pieces of land that cannot be cultivated are fenced for hogs and when large enough may make fairly good pastures, though as a rule, much smaller returns per acre are obtained than from good rotation pastures. When such pastures are already provided on a farm, it is probably not wise to change at once, and in such cases the scheme of rotation suggested above does not apply.

On such farms, if it is desirable to hog off corn, which in very many cases it is intensely practical to do, temporary fences may be used to advantage to fence off from any field of corn, whatever amount can be handled in this way.

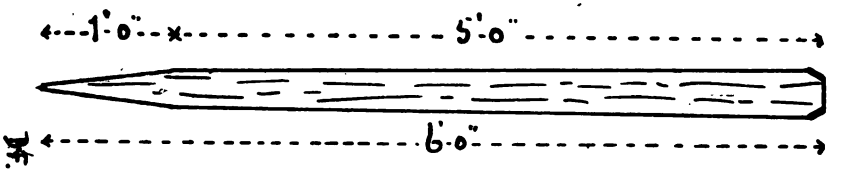


Fig. 10.—A good post for temporary fencing, 3" by 6 ft. Top rounded off so it will not split when driven.

Temporary Fences.

For temporary fences for hogs many farmers use only a plain woven wire ribbon 24" or 26" high, put up on small posts or stakes set from one to two rods apart. The best kind of posts to use for such work are about 3" posts, six feet long, well sharpened, and the corners rounded off on the upper end so they will not split in driving. Holes may be made rapidly with a crowbar and then two or three good blows with a post maul will make the posts solid enough for temporary use. Such posts are easily taken out when it is desired to move the fence. It is much easier to fence hogs into a cornfield than to fence them out, and as a rule, they do not make much effort to get out. In case they do attempt to get out, a barbed wire stretched along the bottom, or stakes one or two feet long driven between posts and left just enough above the ground so that the bottom of the wire ribbon may be stapled to them will keep them on the right side. Such fencing will cost from 30c. to 40c. per rod. (See table XV). The amount of fencing used and the methods employed in handling it (see table XVII will make the cost vary from $1.50 to $3.00 per acre. This will undoubtedly prove more profitable in many cases than husking the corn and feeding in the yard, especially if there is a good growth of rape or other catch crop that the hogs can get at the same time they are getting the corn. In case this is not done, it is more economical to snap corn that is to be fed at once than to carefully husk it.

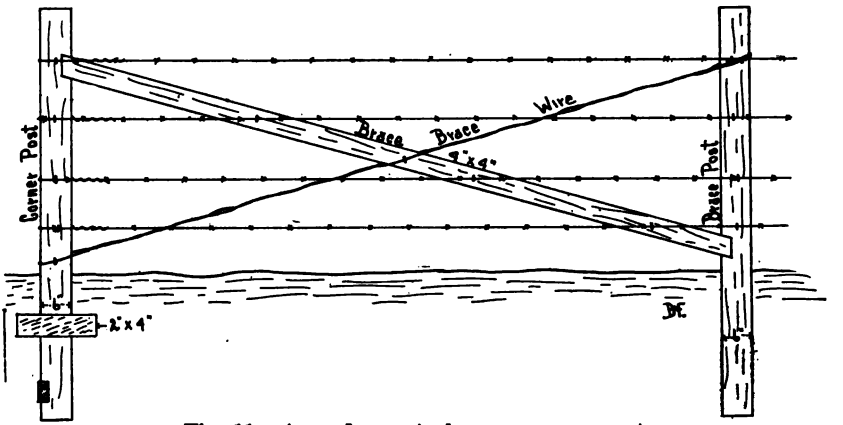


Fig. 11.—A good way to brace a corner post.

Fencing, intelligently done, offers one of the safest investments of any of the farm improvements. Not alone is it valuable to enclose the regular pasture, but it often makes possible the pasturing off of grain and corn fields after harvesting, thus saving from 10c to $5.00 an acre, which would otherwise be wasted. However, like any other investment, it should be made only when careful reasoning shows it to be advisable.

To many farmers, the first cost of a fence seems so great as to be prohibitive, and they refrain from putting up a few rods of it when in reality they would greatly increase their net profits thereby. To others the cost of

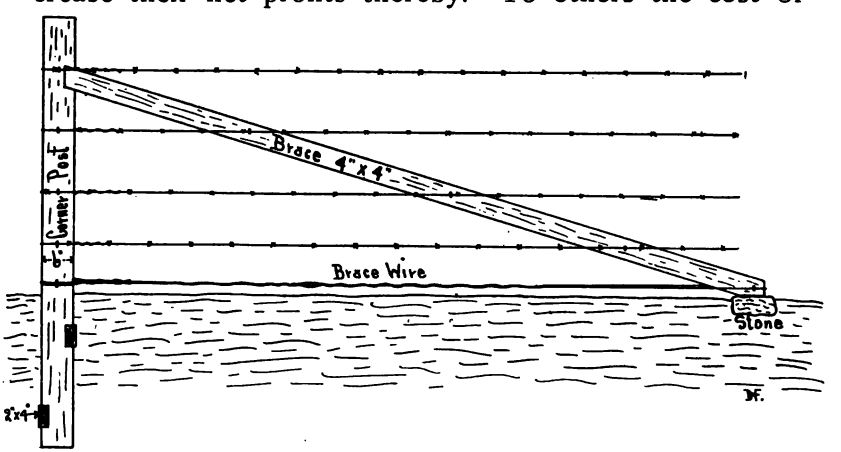


Fig. 12.—A good way to brace a corner post.

fencing seems low. They regard it as a permanent investment, and they build more than they can profitably use.

A fence cannot be considered as a permanent investment for it must be replaced within a comparatively short time and it gradually deteriorates whether it is used or not. Unless there is sufficient live stock on the place to make use of all fences and unless such live stock is of such quality as to return a profit from good feed, fences are not a profitable investment. If one pays $10.00 per acre for land, the annual rental on that land will normally be 6% interest on $10.00 or 60c per acre. If one pays $10.00 to fence an acre of land, the annual charge against that fence will not only be the interest on the investment but also the annual depreciation. This makes the annual cost of the $10.00 fence more than twice as much as the annual rental of the $10.00 land. (a)

Life of Fences.

It is rather a difficult problem to even estimate the length of time a fence will last, for this varies so largely with the soil, climate, quality of material and construction of fence. With a fair knowledge of local conditions and of the quality of material used, however, a reasonably accurate estimate of the probable life of the fence can be made. Then the table (page 95) showing the average annual cost of fences lasting different lengths of time will be found useful in estimating the average annual cost of the fence per acre. For example, it is desired to enclose a square 40-acre field with a 3-barbed wire fence, posts 1½ rods apart. The average cost of such a fence is about 27c per rod. If the fence lasts 10 years the average annual cost is 3.6c per rod. 320 rods of fencing are required to enclose the field. This makes the total amount cost 320×3.6c or $11.52. The average annual cost per acre is 28.8c.

(a) If the fence lasts 10 years, the average annual depreciation will be $1.00 per year. The amount invested in the fence becomes constantly less. Thus: 1st year, $10.00; 2d year, $9.00; 3d year, $8.00, etc. Until the 10th year, when the investment will be but $1.00. The average annual investment will be then the average of these different amounts, or $5.50. The average annual cost of the fence will be 6% interest on $5.50, or 33c., plus the annual depreciation of $1.00, or $1.33.

Cost of Fences.

Many farmers know about how much it costs them per rod to build the different types of fence and for them the following figures may not be valuable. To those who have no such figures, the subsequent table will at least offer a basis from which to compute the approximate cost per acre per year to fence their fields.

The cost of fencing varies in different parts of the state, owing to a great variation in the cost of materials, especially posts, and to a variation in the cost of construction. The cost of construction varies greatly with the condition of the soil, but much more with the methods used and the thoroughness with which the work is done. The following tables show the actual cost of fencing on several farms in the state:

TABLE XII.—Cost of 520 rds. of Fence 26" Woven Wire Ribbon, 3 Barb Wires, Posts 1 rd. apart, on large Farm Operated by Beyer Aune, Morris, Minn.

	Total cost.	Cost per rod.
(a) Labor (total horse and man)	79.56	.153
520 posts (4"x7' cedar) at .11	57.20	.11
26" woven wire ribbon at 22.5c.	117.00	.225
Barbed wire (3 strands)	47.00	.09
Sundries	1.52	.003
Total cost	$302.28	.581

TABLE XIII.—Cost of 320 rods of Fence, 3 Barbed Wires, Posts 1 rod apart, on Farm Operated by Beyer Aune, Morris, Minn.

	Total cost.	Cost per rod.
(a) Labor (total horse and man)	42.88	.134
320 posts (4"7' cedar) at .11	35.20	.11
Barbed wire (3 strands)	28.80	.09
Sundries	.32	.001
Total cost	$107.20	.335

(a) The labor in both cases is higher than average. The fence was very carefully built and a large part of the work was done on wet days when only slow progress could be made, but time was charged at the average rate for the month. However, the material was purchased at a price below the average, so the total price is nearly accurate.

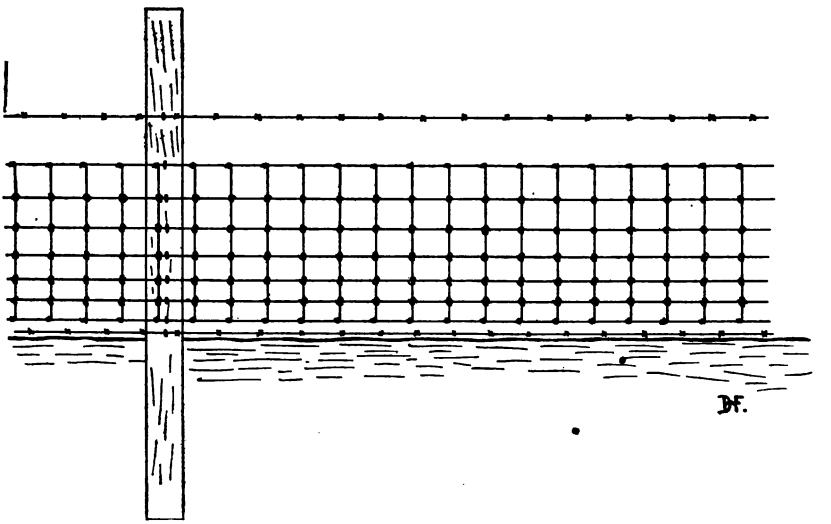


Fig. 13.—A good hog fence.

TABLE XIV.—Cost of 180 rods of Fence, 28" Woven Wire Ribbon, 3 Barbed Wires, Posts 1 rd. apart, on Farm of F. F. Marshall, Grove City, Minn.

	Total cost.	Cost per rod.
180 rods, 28" woven wire ribbon at 28c	50.40	.28
180 oak posts (4"x7') at 10c	18.00	.10
Barbed wire	20.00	.111
Braces and staples	1.80	.01
(a) Labor (two men 1½ days)	4.50	.025
Total cost	$ 94.70	.526

(a) The labor cost is exceedingly low, no horse labor being accounted for, and it is very doubtful if the work could be duplicated for that amount. However, the cost of wire is very high and it is quite probable that the two will about average up so that the total cost is approximately correct.

TABLE XV.—Gives the Actual Cost of Building 132 rods of 26" Fence, Posts 2 rds. apart, at the Experiment Station.

	Total cost.	Cost per rod.
66 4"x7' cedar posts at .18	11.88	.09
132 rods 26" fence at .25	33.00	.25
16 4x4x12' braces at $25.00 per M.	2.25	.017
Setting 66 posts, including 8 corner posts	1.66	.013
Stretching and stapling wire	2.33	.018
5 lbs. staples	.25	.002
Total cost	$51.37	.390

The posts in the fence were all well set 2½ feet deep and the fence might make a permanent fence for hogs by putting in one post between. This would add to the cost $11.88 for posts plus the cost of setting, $1.66. This would give a total cost of $64.91 or a cost of 49.1c per rod. If three barbed wires were added to this the cost per rod would be increased 9c more, making a total of 55c, which is very near the same as on the other two fences.

TABLE XVI.—Cost to Build 108 rds. of Temporary Hog Fence, Posts 2 rds. apart, at the Experiment Station.

	Total cost.	Cost per rod.
49 8" posts, cedar, at .13	6.37	.059
4 5"x8' corner posts at .25	1.00	.009
8 4x4x12' braces for corners	3.20	.030
3 lbs. staples at .05	.15	.001
108 rods 26" woven wire at 25c	27.00	.25
Digging holes and setting posts	1.50	.014
Stretching wire and stapling	1.50	.014
	$40.72	.377

From the above actual cases, which may be taken as fair averages, the following figures as to the cost of different fences are deducted, and they may be taken as fair estimates to be corrected to suit local conditions.

TABLE XVII.—Average Annual Cost of Fencing.

Kind of Fence.	Cost per rod.	Average Annual Cost per rod when lasting 10 years	8 years	6 years
26" ribbon, 2 b. wires, posts 1 rod apart ..	$ .55	7.3c	8.7c	11.1c
2 b. wires, posts 2 rods apart	.19	2.5c	3.0c	3.8c
2 b. wires, posts 1 rod apart	.28	3.7c	4.3c	5.6c
3 b. wires, posts 2 rods apart	.24	3.2c	3.8c	4.8c
3 b. wires, posts 1½ rods apart	.27	3.6c	4.3c	5.4c
3 b. wires, posts 1 rod apart	.33	4.4c	5.2c	6.6c
Any fence	.20	2.6c	3.2c	4.0c
Any fence	.25	3.2c	4.0c	5.0c
Any fence	.30	4.0c	4.8c	6.0c
Any fence	.40	5.3c	6.4c	8.0c
Any fence	.50	6.7c	8.0c	10.0c
Any fence	.60	8.0c	9.5c	12.1c
Any fence	.70	9.3c	11.0c	14.1c
Any fence	.80	10.6c	12.7c	16.1c
Any fence	.90	12.0c	14.3c	18.1c
Any fence	1.00	13.3c	15.9c	20.2c

NOTE.—The last three columns of figures in the above table are offered for the convenience of those who wish to know the approximate annual cost of any given fence. The figures are obtained by dividing the cost per rod of the fence by the number of years it is expected to last and adding to this the interest on the average annual investment. (See Footnote, page 91.) To illustrate how these figures may be used, let us consider the fencing required per acre to enclose the hog paddocks on farm shown in Fig. 21. Sixteen rods of fencing is required per acre. If the fencing costs 55c per rod, and will last eight years, the cost per year is 8.7c. 8.7cx16 equals $1.39, or average annual cost of fence per acre.

ARRANGEMENT OF FIELDS.

Since fencing is quite an item in the cost of pastures and in hogging off corn, the arrangement of fields in such a way as to use the least possible amount of fencing and still have the hogs near the farm buildings so they may be sheltered, watered and fed economically is essential. A piece of land one rod wide and 160 rods long contains one acre and requires 322 rods of fence to enclose it. A piece of land 12¾ rods square contains one acre and requires 51 rods of fence to enclose it. A 10-acre field (40 rds. x 40 rds.) requires 160 rods of fencing to enclose it or an average of 16 rods per acre. It is quite evident from the above facts that the larger and more nearly square a field is the less fence is required per acre to fence it. Likewise, two adjoining fields may be fenced more cheaply than two separate fields of the same size as a portion of the fence answers for both fields. The fact that clover is one of the best crops for pasture and that it cannot be depended upon to live for more than one year's pasturing, together

with the above facts in regard to fencing, suggest at once the idea of a rotation of crops on a few small fields near the farmstead in which the crops may be conveniently pastured. A hog pasture plowed up makes one of the most desirable places to grow corn.

Such a piece of corn land if fenced, could very easily and profitably be fed off with hogs. Corn land disced and well prepared is an excellent place to grow any kind of a grain crop, and clover sown with the grain crop on such soil has an excellent chance of being in good condition for pasturing the following year. Thus a productive three year rotation is naturally worked out. See Fig 14.

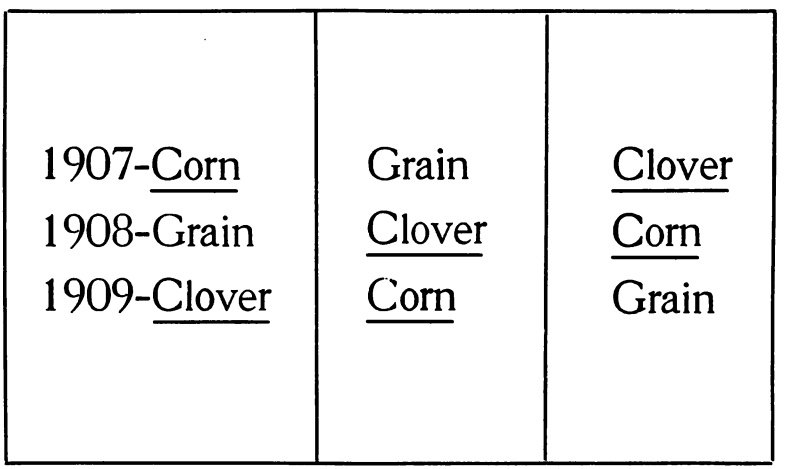


Fig. 14.—Three year rotation for hogs. Crops underlined are to be fed off.

All that is necessary to carry out such a rotation is three fields of nearly uniform size, located near the farmstead. The annual cost of fencing the *three* fields would have to be charged against *two* fields (the corn and clover fields) since the fence would be of no value to the grain field. In considering the amount of hog pasture needed, and the amount of corn that can profitably be fed off, it is found that at least twice as many acres of corn can be used as of pasture. Thus, in a three year rotation, if the field were about the right size to furnish the pasture needed, not enough corn would be furnished. A four year rotation, with one field in grain, one in pasture, and two in corn, would furnish about the right amount of both. Four

fields permanently fenced near the farmstead would make a more desirable rotation than would three fields, and the cost of fencing will be less since the fence would be in use three years out of four rather than two years out of three.

1907-Corn	Corn	Grain	Clover
1908-Corn	Grain	Clover	Corn
1909-Grain	Clover	Corn	Corn
1109-Clover	Corn	Corn	Grain

Fig. 15.—Four year rotation for hogs. Crops underlined are to be fed off.

AMOUNT OF PASTURE NEEDED FOR HOGS.

One acre of average clover pasture will furnish ample feed for two sows and their litters, (the average litter being about seven pigs). Some seasons the clover will get ahead of the pigs, but clover pasture is so cheap a feed that no hog raiser can afford to run the risk of short pastures. Surplus clover in a hog pasture can be utilized for hay or other stock. *A shortage of pasture necessitates supplying the deficiency by other feeds costing two to four times as much.* On farms where six brood sows are kept about three acres of clover pasture should be provided. Six sows on the average would yield from forty to fifty pigs. The pigs would be able during the fall to feed off about six acres of average corn. A four year rotation on four 3-acre fields would about meet the needs on a farm keeping six brood sows.

In laying out a rotation for hogs the number that it is desired to keep should be decided upon—then the size of the fields can be determined. The larger the fields used, other things being equal, the cheaper the cost of fencing

per acre, and the more conveniently the fields are worked. However, it is not advisable to fence hog tight very much more land than can be conveniently utilized by hogs as cheaper fences that are just as effective may be used for cattle.

Some of the important points to consider in laying out a practical rotation for hogs are: 1st, number of animals to be kept; 2d, convenience in feeding while in the field; 3d, shape of fields so that they may be easily worked; and 4th, the least possible number of rods of fencing to the acre enclosed. With these points before one, and each considered, a rotation may be laid out intelligently and to fit most any farm.

The following plans are offered as suggestive of how several farms have been re-planned to allow for a rotation for hogs. These plans are chosen to show how the suggestions in this bulletin may be applied to farm conditions. They also show the value and economy of planning a farm for a definite purpose. The amount of fencing required per acre to enclose the hog lots on these different farms varies from 16 to 29 rods.

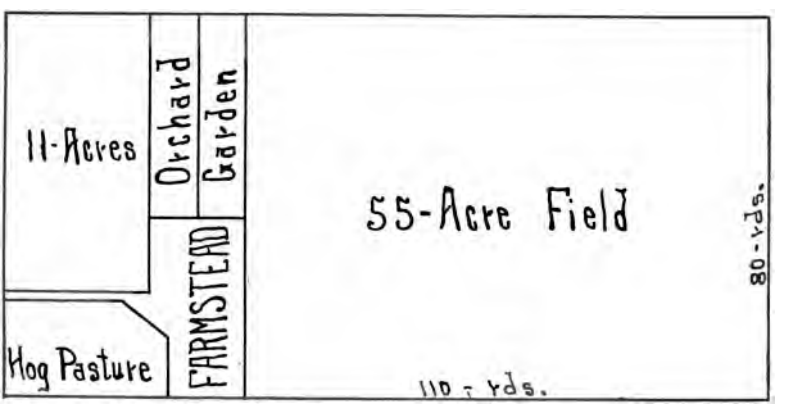


Fig. 16.—80-acre farm. Original plan.

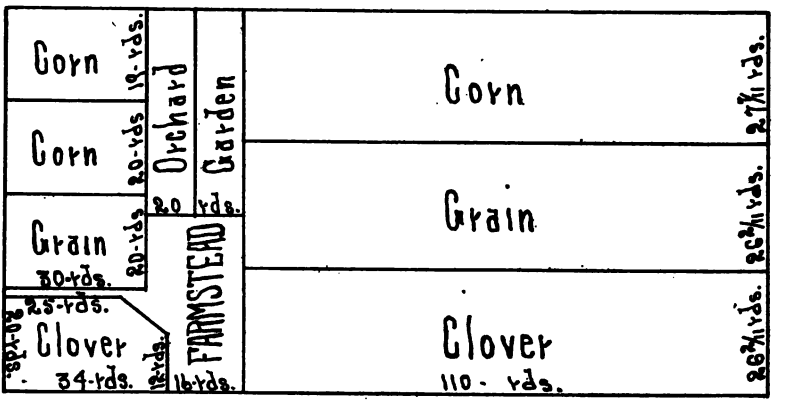


Fig 17.—80-acre farm. Revised plan.

NOTE.—Figs 16 and 17 show an 80-acre farm situated in Southeastern Minnesota. The eleven-acre field in the northwest corner has been divided into three fields which, with the four acre field in the southwest corner makes four fields of approximately the same size. This provides for a four year rotation for hogs. Three hundred forty-eight rods of fencing are required to enclose it, or about 29 rods per acre, when the whole is charged against the three fields used each year. Such a rotation will accommodate conveniently six or eight brood sows and their litters. The winter feed for the sows, the grain fed to the sows and pigs during the summer to supplement the pasture, and in some years a few weeks feed for the pigs in the fall to fit them for market, will necessarily have to be provided from some other part of the farm. Even though another ten acres of land is needed to supply the extra feed, the prospect of profitable returns is good, for the labor cost of producing pork is here reduced to the minimum.

The remainder of the farm is divided into three 18-acre fields, for a rotation of corn, grain and clover. The whole arrangement makes the farm well adapted to dairying and hog raising.

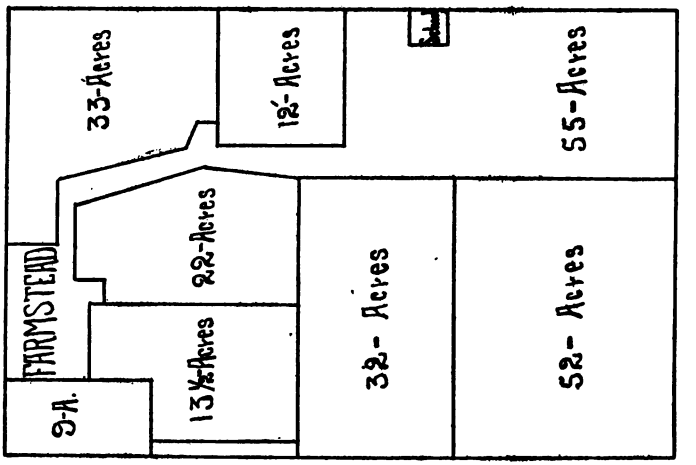


Fig. 18.—Original plan.

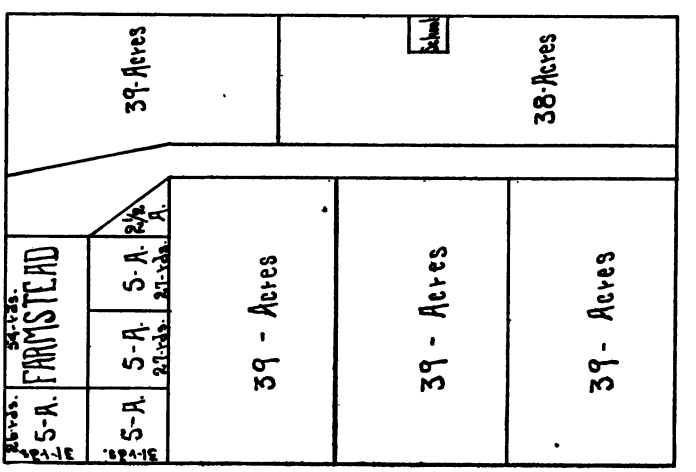


Fig. 19.—Revised plan.

NOTE.—Figs 18 and 19 show a 240 acre farm also located in southeastern Minnesota. The arrangement, shape and size of the fields in the small rotation for hogs is better than in the preceding plan, and the cost of fencing is less. But 372 rods of fencing are required to enclose the four five acre fields. If the whole of the fencing is charged against the three fields used, 25 rods of fencing are required per acre. The cost of building and maintaining that amount of fence divided by the number of years it will last will give the average annual cost per acre of fencing. The fields are so located that each is easily reached from the farmstead and they are large enough to accommodate ten to fourteen sows and their litters.

The remainder of the farm is divided into five 39 acre fields for a five year rotation. The irregular strip or ravine through the center of the farm is used for a lane and for permanent pasture.

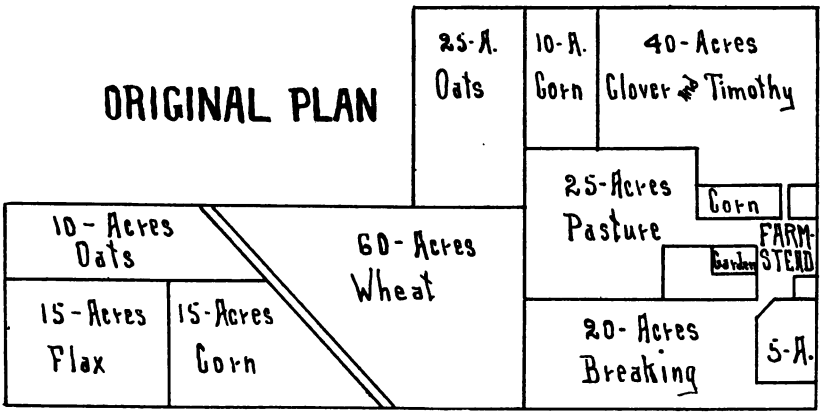


Fig. 20.—Original plan.

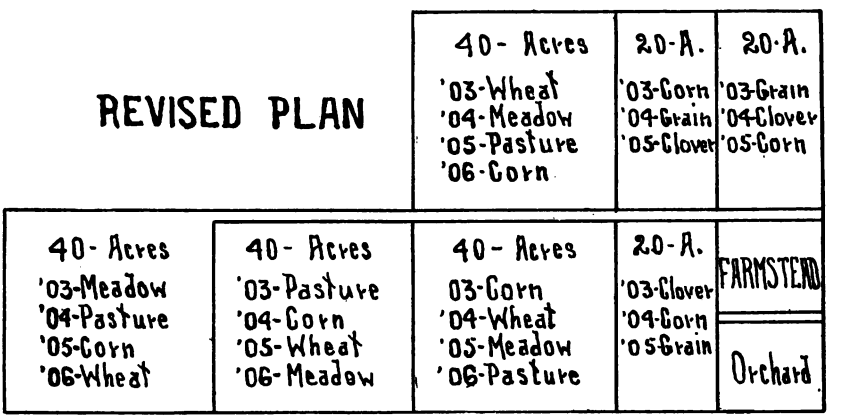


Fig. 21.—Revised plan.

NOTE.—Figs 20 and 21 show the orginal farm plan and the plan revised for a systematic rotation. This 240 acre farm is in Western Minnesota. The three 20-acre fields are planned for a minor rotation for hogs, 640 rods of fencing are required to enclose these fields or on average of about 16 rods of fencing per acre, that is, on a two field basis.

It will be observed that the cost of fencing per acre is very low since such large fields are used. There are very few farmers on 240 acre farms who keep enough hogs to use 20 acres of clover pasture to advantage. To be sure, a part of the clover may be cut for hay, but this would make no use of the expensive fencing, hence the cost of fencing 20 acres would have to be charged against the five or ten acres actually used for hog pasture. (See following paragraphs.)

The plan shown in Fig 21, might work very nicely and really be economical, if enough sheep were kept to make use of the extra pasture. In case it was deemed unwise to allow the hogs and sheep together the 40 rods of mov-

able fence (mentioned later) might be stretched across the field at a very slight expense.

This arrangement would make good use of the 20 acre clover pasture and the chances of sheep returning a good profit on such cheap pasture are excellent. The cost per acre for fencing on this farm is but little more than half that on the 80 acre farm shown in Fig. 17.

Hogging a 20-Acre Field of Corn.

If from 150 to 200 hogs were raised, the 20-acre corn field could be easily fed off by them. And here again would be realized the advantage of large fields. The cost per acre of the outside fence would be about $1.20. Forty rods of movable fence would be necessary so as to fence off a portion of the field which could be used by the hogs. This would cost about $10.00. Since this strip of fencing could be used for many years, the annual cost per acre would not exceed 10c, making the total cost per acre for fencing this cornfield hog tight and in plots about $1.30. It would cost from $3.00 to $5.00 per acre to pick and feed this corn. Hence, there is a saving of from $1.70 to $3.70 per acre by feeding off the corn as it grew in the field.

The Larger or Major Rotation.

The remainder of the farm is arranged for a four year rotation of corn, grain, meadow and pasture. This makes a good rotation for a diversified farm, and should keep the soil in a high state of productivity.

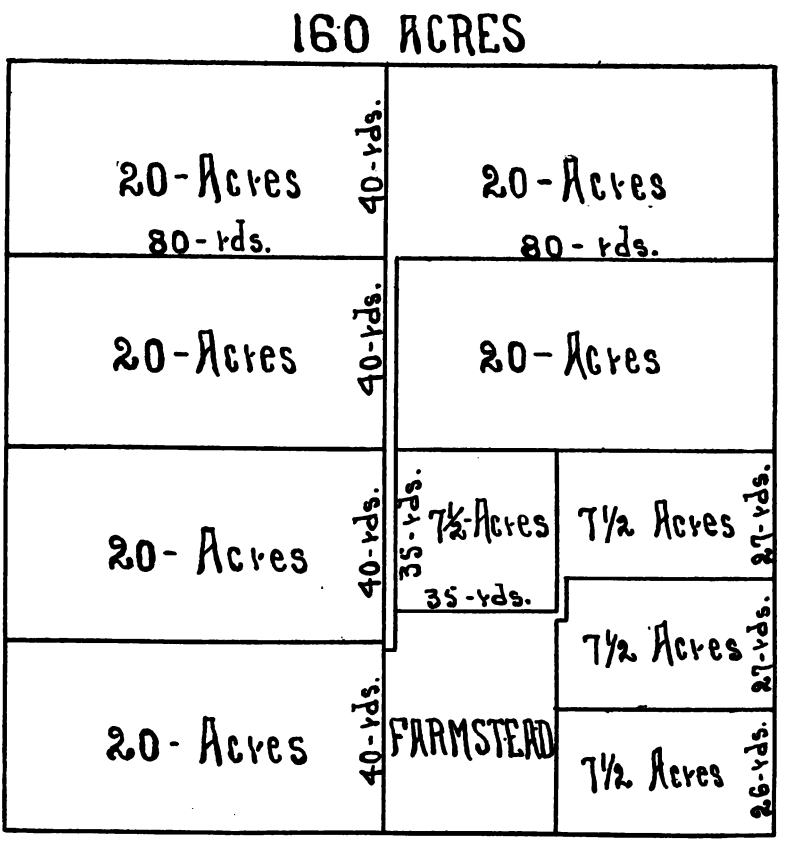


Fig. 22.—An economical arrangement of Fields.

OTE.—Fig 22 shows a convenient arrangement of a 160 acre farm that is all tillable, for diversified farming. The four 7½ acre fields are so arranged as to be very economically fenced and they are all conveniently situated. Less than 20 rods of fencing is required per acre when all the fence is charged against the three fields actually used. If the fence costs 55c per rod, and lasts ten years, the average annual cost per acre of fencing will be less than $1.50.

The rest of the farm is planned for a six year rotation on six 20-acre fields. Such a rotation may be adapted to almost any class of farming. It will be noticed that very little lane is necessary to get to all of the fields and that the fields lie so that very little time is spent in getting from the buildings to work.

FIELD OBSERVATIONS IN HOGGING OFF CORN.

Kind of Corn to Grow.

The variety of corn usually grown in a locality is the proper kind to grow for hogging off purposes, since it is probably best adapted to the locality and gives the largest yield. However, getting an early start in the fattening process is very advantageous, and it sometimes happens when pasture supplies are short or the early sale of hogs is desirable, that such a variety does not mature early enough. To be prepared for such conditions, it is well to grow a sufficient amount of sweet corn or early maturing flint corn to tide over until the field corn is ready for use. No more than is sufficient for early fall feeding should be grown since it costs just as much to grow these varieties as it does the dent and they yield much less. Flint corn is preferable to sweet corn for hogs; and field feeding of flint corn gives better results than where husked and fed after the corn has hardened.

One of the great objections in growing flint and other early varieties of corn has been the difficulty of harvesting them. Feeding them off with live stock eliminates this objection, and it would seem that they might be grown and utilized more extensively, particularly *in the northern part of the state.*

Size of Pigs to Use.

Pigs weighing from 100 to 140 pounds are best suited for field feeding since they have at that weight formed a good amount of bone and muscle for framework, and are in a condition to fatten rather than to grow. Those that have been grown on pasture are better fitted for the work than those that have been confined in pens, as they are more active, and have had more experience in gathering food for themselves. They, therefore, eat corn more readily and require less amounts of expensive mill feed. Shoats of this weight may be expected to gain about 1.4 lbs. daily. In 60 to 70 days of feeding they should gain approximately 92 pounds.

Hogs weighing from 200 to 240 pounds almost always bring good prices. It is not unreasonable then to expect to start with pigs that weigh from 110 to 140 pounds. If farrowed in early April, pigs will make these weights by Sept 10th.

Old brood sows that are thin in flesh fatten up very quickly when turned into a field. A few weeks on early varieties of corn will usually permit such sows to be marketed early or before it would be possible following the common method of feeding.

WATERING.

While eating corn in the field hogs require a great deal of clear water. They grow and thrive better when they have it, and some means of supplying it to them fresh, and in large quantities, must be provided. When in the field, hogs do not come up and drink in droves as they do in the yards; therefore, it is necessary to keep water before them continually. When fields adjacent to the farmstead are used, hogs can be brought up to the yards and watered or fed slop as usual; where fields remote from the farmstead are used, the simplest way is to fill several barrels or casks with water and haul them by team on a stone boat or other conveyance to the field. Enough can thus be taken out at a time to last for two or three days.

When a plentiful water supply is assured, slopping does not require such careful attention. Many feeders do not slop at all, but better results are undoubtedly obtained by supplying some sort of bone and muscle producing feed to pigs weighing under 140 pounds. Old hogs do not need it, but young ones do. In the early fall when on a rape or clover crop, or when green feeds of any sort are plentiful, once a day is all that is necessary to slop the hogs, but as the season advances, they should be slopped at least twice a day. Shorts, middlings, or oil cake and shorts combined are good growing foods, and hence are good materials for slops. Experiments have not yet been carried on to determine the extent to which slops should be used, but careful observations and experience warrant the above remarks.

Where possible, the place of watering and slopping should be changed about in the field. This is necessary in order to avoid too much mud and filth in one spot, and to

distribute the manure over the field more uniformly. This is one great advantage in hauling water and slop directly to the field as occasion demands, rather than bringing the hogs to the yard.

Time to Turn Into Cornfields.

Many farmers believe that green corn brings on cholera and, therefore, think it unfit for hogs. It is true that immature corn will often make hogs scour, and when in this "below normal" condition, they are, therefore, more easily infected by hog cholera, but hogs that have had free access to green pastures at the Minnesota Experiment Station were not affected by the corn in any stage of its growth. Some men who have very successfully hogged off corn say, "Turn hogs into corn at any time." It is very likely therefore that one can, in so far as safety is concerned, turn them into the corn at almost any time, but more experimenting is necessary along this line before the question can be answered unconditionally. Even though it may be safe to turn in early, it might not be wise, for a smaller amount of feed is obtained when the corn is not allowed to ripen first, and the pigs are likely to tear it all down before it matures. When to turn in will, therefore, depend upon the amount of available pasture and the nature of the pigs as well as upon the development of the corn. It is safe to begin hogging the field corn about the time it is dented, or from Sept. 1st to 15th.

Size of Field to be Hogged off at One Time.

There is no definite data at hand to determine just how large an area it is advisable to allow hogs at one time in feeding off corn. Results at the Minnesota Station show that where it took the hogs twenty days to clean up a field of corn they did not make as good gains during the latter part of the period as during the earlier part. Some farmers who have tried it claim that as good results are obtained by turning into the whole field at once as by fencing into lots. This is a matter to be settled largely by circumstances such as the price of labor, the shape of the fields, the cost to fence them, and particularly the soil and climatic conditions. Where there is much rain and the soil is sticky the areas should probably be limited so that they can be cleaned up in twenty days or less. Where there

is but little rain, and the soil is sandy or gravelly, there is perhaps no good reason for limiting the amount of corn beyond that which they can consume before the end of the season. If by mismanagement or accident any part of a field is left unfinished brood sows or stock hogs may advantageously be used to clean it up, and if the amount is large, then they should be turned in for only a short period at a time, as their breeding qualities are easily injured by excessive corn feeding.

For convenience, a table has been arranged showing approximately the number of days required to hog off an acre of corn yielding various amounts in order to enable the feeder to judge as to the acreage of corn he will need to enclose at a time for his pigs.

TABLE XVIII.—Showing Approximately the Number of Days Required to Hog Off an Acre of Corn by a Given Number of Pigs Weighing 125lbs.

Note.—Pigs should not be on one field for more than 20 days, and better if only 14 days.

	Average weight of Pigs	WITH CORN SHRUNK TO JAN. 1, and YIELDING:								
		30 bu. per acre	35 bu. per acre	40 bu. per acre	45 bu. per acre	50 bu. per acre	55 bu. per acre	60 bu. per acre	65 bu. per acre	70 bu. per acre
	Lbs.	Days	Days	Days	Days	Days	Days	Days	Days	Days
Will keep 10 Hogs	125	22.5	26.2	30.0	33.7	37.5	41.2	45.0	48.7	52.5
Will keep 20 Hogs	125	11.2	13.1	15.0	16.8	18.7	20.6	22.5	24.3	26.2
Will keep 30 Hogs	125	7.5	8.7	10.0	11.2	12.5	13.7	15.0	16.2	17.5
Will keep 40 Hogs	125	5.6	6.5	7.5	8.4	9.3	10.3	11.2	13.2	14.1
Will keep 50 Hogs	125	4.5	5.2	6.0	6.7	7.5	8.2	9.0	9.7	10.5
Will keep 60 Hogs	125	3.7	4.4	5.0	5.6	6.2	6.8	7.5	8.1	8.7
Will keep 70 Hogs	125	3.2	3.7	4.3	4.8	5.3	5.8	6.4	6.9	7.5
Will keep 80 Hogs	125	2.8	3.3	3.7	4.2	4.6	5.1	5.6	6.1	6.5

SHELTER.

Comfort is highly essential to the growth and well-being of pigs; and while they are out in the fields, shelter of some sort must be provided for them. Early in the season a bed of straw answers the purpose very well, but later when the cold chilly rains, begin, more protection is necessary. Where hogs are near enough to permanent buildings so that they can enter them at will, no temporary buildings of course need be provided; but where

they are in remote fields, the lightly built, movable hog-house which is used for brood sows and which may be at hand, is both convenient and serviceable. Some cheap means of shelter is absolutely necessary for cold, damp beds lead to the dangerous "piling up" of pigs, if not to colds and pneumonia.

WHAT MINNESOTA, IOWA, KANSAS AND INDIANA FARMERS THINK OF HOGGING OFF CORN.

Favorable reports of hogging off corn having been secured at the Experiment Station. Reports of work as conducted by farmers in the State and elsewhere were considered desirable. Seven farmers in Minnesota and nine in other states made reports. All were favorable to this system of harvesting. Replies were secured from the following in Minnesota:

G. G. Robinson, Kimball, Stearns Co.
F. F. Marshall, Grove City, Meeker Co.
Charles Putzier, Litchfield, Meeker Co.
Asa B. Knapp, Northfield, Rice Co.
Paul Sherman, Sleepy Eye, Brown Co.
A. B. Thompson, Dodge Center, Dodge Co.
Wm. Rathjen, Kanaranzi, Rock Co.

Letter from Mr. G. G. Robinson.

I have practiced "hogging off" the last three years and think it is profitable, especially so when labor is so expensive. The first two years I had three acres of corn sown to rape for my hogs to run in and this year I had an additional lot of four or five acres. My lots come down to a little creek at one end where the hogs have plenty of water to drink and to wallow in. They also have a meadow where the hay was cut early and it is surprising how much of their time they spend there.

Now—as to waste—it is practically nothing. Go over the field a few days or a week after turning the hogs on and you will think it is a serious objection, but I have always found in the end that they pick the corn up until the ground is practically clean. I think the waste is a negligible quantity as compared to the time and labor—hired labor—that it would take to get the corn to the hogs. It usually is the case that a farmer is so busy that he cannot commence feeding his hogs as early as he desires, but hogging off obviates this difficulty—the hogs

fatten themselves. This leads to another point: I prefer Flint corn or some other early kind, especially for this first feeding, so I pull and carry the corn to the hogs for a week before turning them in to get them used to it.

Mr. F. F. Marshall's Letter.

Yours received and will say that my hogs are now in the corn field. I cannot supply you with much data owing to the fact that I have no way of weighing the hogs or of estimating the amount of corn, it having drowned out in spots.

I believe hogging off corn is just the thing. I know the waste is less than it could possibly be under the old method; the hogs will make a heavier gain. As I write now (a little after six) I can look out and see the pigs digging for clover roots. They have been to breakfast. Last year I am positive that I had a bunch that gained three pounds a day. When I took them to market they weighed on the average 303 pounds and no one estimated them over 250 pounds. Their flesh was very hard and they were very active. They did not appear to carry so much flesh.

I heard some ridiculous things concerning hogging corn. One man, a year ago, said he though when a person had the advantage of an agricultural education he would be ashamed to be so slack. I met that man again last winter. Now his hogs are hogging off his corn and he is delighted with the result.

Report of Asa B. Knapp.

Received your letter and will try to answer your questions as well as I can. I have no scales to give exact weights. I wish I had. I could then tell just how much the drove of hogs gained on each different feed, peas, barley, oats, rape and corn; and how much pork was produced from each field and each variety of feed.

I have been turning my pigs into corn each year for the past five years. I find the best time to turn them in is when the corn is denting; but one should not turn them in then unless they are used to the feed, having barn fed them generously for a week. I have tried flint corn but do not like it. I turned my pigs into a five acre piece of

Mercer flint corn three years ago this fall. They did not eat it up clean nor did they seem to do quite as well on it. They had five acres of yellow dent corn right beside the flint. They cleaned the dent all up first. I like sweet corn very much. I cut it, stalk and all, and they like it very well, eating a good deal of the stalk.

I feed shorts and a flour middlings mixed in a slop twice a day while they are first in the corn, then once a day after they have been in a week. In a few days I stop this entirely and keep fresh water before them all the time. I don't believe I have ever turned hogs into corn before they have weighed a hundred pounds. My experience teaches me that only a small part of a pig's ration should be corn until he has reached the weight of a hundred pounds.

I think that there would be more corn wasted hogging off if the brood sows were not turned in after the fattening hogs, than there would be husking the corn and feeding in the yards. But every farmer has brood sows and the exercise and green feed they get during the fall until snow flies, from Oct. 1st, on, alone pays for the fencing. The sows do so much better when they farrow the next spring. In hogging off corn one must figure and plan his work ahead. To get the best results pigs should come early and all be as near the same age as possible.

Report of Paul Sherman.

Upon your request, I shall endeavor to give my experience "hogging off corn" this fall.

Before cultivating the corn the last time I sowed four pounds of rape in an acre of corn that was not a good stand. The rape grew quite well and this field was fenced and twenty-one spring pigs turned in after the corn was nicely dented.

Before turning them in I weighed four of the average sized ones. Their weights were as follows:

No. 1—133.
No. 2—126.
No. 3—102.
No. 4— 99.

There were thirty-five bushels of corn in the field and they were confined to this field entirely with plenty of water all the time. They cleaned up all the corn in the

field and when they got through it would have been hard to find a kernel left in the whole field or anything but the stubs of the rape.

The last few days they were in there, the corn being nearly gone, I gave them a feed of shorts at night. In all they had 65 lbs. of shorts.

They were in this field twelve days and their weights were:

No. 1—151—gained 18 lbs.
No. 2—153—gained 27 lbs.
No. 3—126—gained 24 lbs.
No. 4—120—gained 21 lbs.

This would be an average gain of twenty-three pounds each or 667 lbs. on all twenty-nine.

I am greatly pleased with the trial for the results were far beyond my expectations. I am going to do more of this work next year, but in addition to this, I shall have a pasture of timothy and clover for them to feed on.

Letter from Charles Putzier.

I turn my hogs weighing from 50 to 100 lbs. into the corn field when corn is about right for roasting. If the pigs are small I feed shorts while they are on corn. It is better to let them run over a small portion of the field at a time. The waste of corn is very small. I think it takes longer to fatten in the field than in the yard because they do not rustle when they begin to fatten, but hogging off saves time and labor.

I make a practice of raising all my pigs on pasture. When the corn suits me I open the gates and let the hogs help themselves. By this system the manure is spread over the field. Hogs do not make corn ground difficult to fit. Clover and timothy sod bother me much more. I have practiced hogging corn a little for years and think it is all right. The work is lightened in the fall, just when labor is high-priced and hard to get.

Letter from Wm. Rathjen.

I turn hogs into corn when it is fully matured. Pigs weighing 125 to 130 lbs. are the best. I find it is not as profitable to feed 75 lbs. as 140 lbs. pigs. I do not feed mill feeds or slops often at this weight. Hogs do best when a small portion of the field to be hogged is fenced

off at a time. Handled in this way it takes from 100-110 days to fatten pigs of the above weight, and no corn is wasted except possibly in real muddy weather. My hogs will do better in a field than in a yard if in addition to corn, rape and clover is fed. Less labor is required and in that way it is a great saver.

The effect of the hogs on the field is good or at least the crops on the land the following year always show extra good yields. Hogs root little except in Morning Glory beds.

LETTER FROM A. B. THOMPSON.

I have not been at the hogging off corn business long, but I think it the nicest way to grain and feed hogs there is. As for help, it is almost impossible to hire and pay the prices they ask. From twelve sows I sold $1,044.00 worth of pigs, selling everything with the exception of keeping twelve young sows. I had good luck, plowed 100 acres, exchanged help in threshing, and took care of my hogs. My corn field is fenced. I turned 100 pigs into about three acres at a time. I used a woven wire fence and moved this in about half a day. If I had husked the corn it would have taken me all day throughout the season. This was a great saver of time.

I think the corn field is a good place for pigs after they weigh 50 lbs. and the corn is in the milk. I fed some shorts, but I think rape is just as good. Running or fresh water is excellent. By feeding corn in the field and shorts in slop my April pigs last fall weighed 225 lbs. by November, and no corn was wasted. I usually have a smaller bunch of pigs following the larger fattening bunch.

In the corn field the pigs grow faster and larger than in the yard.

I think that yard feeding can not be compared in any way with the field feeding. More and cheaper gains are secured; fertilizer is better distributed and the cost of caring for and harvesting the corn is greatly reduced.

Following are the names of some farmers from other states who have followed this system and who have answered questions bearing upon it:

1. Case Noteboom, Hawarden, Iowa.

2. Joseph Aleck, Logan, Iowa.
3. John Brown, Logan, Iowa.
4. J. E. Exton, Mulvane, Kansas.
5. H. V. Packenpough, Logan, Iowa.
6. H. Rosenquist, Oakes, N. D.
7. E. C. Stone, Armstrong, Ill.
8. J. A. Hunt, Logan, Iowa.

These men will be referred to by number in the replies that they make to subsequent questions.

Question: At what age do you usually turn hogs into the corn?

1. The young pigs when the corn is "laid by" and the old when it is fit to feed.

3. From 100 to 150 pounds; weight makes no difference.

4. 100 to 140 pounds.

5. I turn pigs in after corn is five inches high. They start to tear it down when corn is in roasting ears.

6. All sizes after husking the best corn.

7. From weanlings to 150 pounds.

8. 75 to 100 pounds.

Question: At what time should they be turned into the corn field?

2. About September first.

3. When corn dents.

4. When corn shells.

5. When corn hardens.

7. As soon as corn will do for pigs to eat. If weanlings, they may be turned in as soon as the corn is past the milk stage.

8. From the fifteenth of September to the first of October.

Question: Do you feed shorts to pigs while they are hogging down corn, and do you think it necessary to feed some sort of mill stuff if one grows rape in the corn field or has clover pasture to which the pigs have access?

3. Shorts are fed twice a week or let pigs run in a clover pasture to balance the ration.

4. No.

5. Feed wheat ground very fine and one-fifth oil meal. Also clover and rape pasture.

6. Do not consider it necessary, but if cheap, it is all right to feed.

7. No. Rape, however, will supplement corn better than mill feed. A pint of tankage to a pig is the best I ever tried. This is not necessary if he has clover.

8. No.

Question: Do you believe that the hogs should be given a chance to run all over the corn fields that are to be eaten down, or do you think it would be better to fence off a small portion of the field at a time?

1. I turn into 40 acres at a time. I fence my land with an eye for convenience rather than with a desire of feeding off the corn.

2. Turn into twenty acres after saving 400 bushels.

3. Let run all over 20 or 80 acre field, but if they cannot finish it before snow flies, husk the standing corn.

4. I think 100 hogs should be confined to 300 bushels of corn.

5. Let them run over as much field as they will clean up.

7. Shoats weaned may be given liberty of field, yet this depends on the season. If dry, will have to break down some or turn in a few old sows.

8. Put in enough to clean field before the spring work begins.

Question: Do you find that hogs waste corn when they are permitted to gather it themselves?

1. I will wager that my hogs do not waste a teacup of corn to the acre.

2. I see no waste.

3. No waste.

4. Hogs do not waste corn.

5. No corn wasted.

6. No, not if a sufficient number are turned in. If there is any left the pigs will get it in the spring.

7. No, I have never found a peck of waste per acre. Further, they will clean the field as they go, commencing at the entrance.

8. No waste.

Question: Does muddy or snowy, damp weather increase the waste of corn when fed in the fields?

6. Yes.

7. Yes. Such times field should be fenced patch at a time. If corn stands well and only shoats are used, fencing is not necessary.

8. It would, if hogs were taken out before field is dry enough for them to pick up the corn.

Question: Do you think it takes longer to fatten the pigs in the corn field than when feeding the corn in the yards?

1. No. It gives more thrifty pigs.
2. Never had hogs do better.
3. They do better.
5. It is way ahead.
6. No, not if they have all they will eat.
7. No, by all means. They will fatten much faster in the field.
8. No.

Question: How do you handle the fencing proposition, and do you think that you could afford to fence the corn field rather than husk the corn?

1. Fencing is a problem, but the expense of husking will more than pay for it.
3. I use woven wire fence. The first year pays for the trouble.
4. Would rather fence than husk.
5. Cannot afford to raise hogs without fencing the corn field.
6. I have not fenced corn field, but let them have the run of the farm, as they find much waste grain in the fields.
7. Yes. There is enough feed lost each year in the fields of Illinois to fence them. Every field on the farm where profit is made is hog tight. On my 180 acre farm I have 80 rods of portable board fence. This can be put anywhere in the field and moved by one man in half a day.
8. My farm is fenced hog tight. I think anyone can afford to fence the field rather than husk corn.

Question: Do you think it is as profitable to hog off corn with 75lb pigs as with those weighing 140lbs.?

3. Any age is all right, but more protein feed must be fed. If very small, let older pigs in to break down the corn. Keep brood sows out.
6. Yes. But to small pigs I would feed something that contained a large amount of protein in addition.
7. I can see no difference. They get something in the corn field they cannot get anywhere else. Never turn a ringed pig into the cornfield.

8. Yes.

Question: Do you think more fertilizer is secured for the field when the hogs run over it, or when the manure is hauled from the yard in which the hogs are fed? If so, have you any evidence to offer in this regard where crops have annually been grown?

1. I have tried it, hogging down twenty acres and snapping twenty acres beside it, and then sowing both to wheat, giving the fields the same cultivation. The hog field made almost five bushels per acre more. Of course the value of corn stalks is lost in hogging and they are worth considerable.

3. Benefits the land greatly.

4. More fertilizer is left when the hogs are in the field.

5. The fertilizer secured will almost keep the soil in good condition if corn is grown three out of four years.

6. If hogged off it will all be left in the field.

7. I once made a test of hogging off in regard to the fertilizer left. A 46 acre field of uniform clover land was broken up and planted to corn, the yield being 85 bushels per acre. The following year it was again planted to corn and partitioned off in the middle with a fence. Half was husked at four cents per bushel and the other was hogged off. The pigs hogging off the corn gained one-half pound a day more rapidly than those following the steers. The next year the same field went back to corn for the third time. Where the corn was hogged off the ground worked better and two and one-fourth bushels of corn per acre better yield were secured.

8. More fertilizer secured in the field.

Question: Do hogs leave the land in such a rough condition that extra work is required to level it down before the subsequent crop can be sown?

1. No.

5. No, it does not.

6. I ring my hogs if they root when I do not want them to.

7. No, but they leave it in better condition to make a good seed bed the following spring. They root it up and plow it, but not deep; winter slacks it down and mellows it until it handles fine in the spring.

8. No.

Question: How long have you followed the system of hogging corn, and what do you think of it?

1. I have hogged corn for ten years and in that time have fed off 1,000-1,200 acres. I think it is the best system because it saves husking, saves time and labor, and enriches the soil immensely.

2. Have hogged but one year. So well pleased will try it again.

3. It saves labor. Don't have to look after the pigs. Hogged off for three years.

4. Three years. I think the system is all right. It is the most economic plan I ever tried.

5. Three years. It is the only way.

6. Two years. Saves work in the busy season. I think hogs do so much better when they have their liberty.

7. Four years. I shall feed no more corn from the time the corn is ready to turn on until the hogs need housing in the winter.

8. Four years. I think it is the only way to feed hogs.

8. Four years. I think it is the only way to feed hogs.

Question: Do you think this system of hogging corn lightens up the work in the fall if the hogs can be turned into the corn field?

1. Yes, a great deal.

3. Yes. Hogs do their own feeding.

4. Goes a long way towards solving the hired help problem on the farm.

5. It does. I have become so disgusted with the help question that I now turn my farm over to the hogs. They get almost as good returns as when I have the hired men, and I have no bother with them.

6. In favor of hogging corn.

7. In Illinois it saves 5 cents a bushel on all corn consumed by hogs.

8. Yes.

The following shows what was done by Mr. Barney Simison in Indiana:

"My experience in one instance, viz., the year of 1905, is the only year that I have followed the hogging off of a corn crop where I kept dates and weights, and can give reliable data concerning the same, although my experience in this line has always been very satisfactory to myself.

"During the month of September, 1905, I decided to allow my shoats (101 in number) to gather their own feed for a time; and having anticipated the same during the early summer, I had sown seven acres of corn (during the last plowing) with Dwarf Essex rape seed, and having an abundance of rain to insure germination and growth, the rape did remarkably well, and when the corn was well enough matured to feed to hogs safely the rape was from ten to twelve inches high and a good even stand. I began feeding the seven acres of corn by cutting and throwing over the fence to the hogs or shoats on the fifth day of September, and on said date I weighed the 101 head and they averaged 79 lbs. each, the lot weighing 7980 lbs. After cutting and throwing over the fence and gradually increasing the amount fed for about ten days, I turned the shoats into the patch to help themselves. The corn was a splendid crop, probably averaging from 85 to 90 bushels per acre. The shoats all did exceedingly well, there not being a sick one during the time they were fed. On the twenty-fourth day of October the corn seemed to be all consumed and the rape as well. That date being a very rainy day and not suitable for weighing the hogs, I turned them out into their former pastures and fed them husked corn for that day, and the next day being a dry day, I got the hogs up and weighed them. The lot weighed 18,080 lbs., which showed an average gain of 100 pounds each for the fifty days they were thus fed. I sold these hogs a few days later at $4.85 per cwt. at home and weighed at home. As feeders or stock hogs these shoats were worth $5.00 per cwt. at the beginning of the feeding period given, which would be 7980 lbs. at $5.00, or $398.95. They were worth $4.85 when feeding period ended, or 18,080 lbs. at $4.85 per cwt., amounting to $876.88. This shows a balance for feed consumed of $477.93, equal to $69.56 per acre for the seven acres of corn and rape consumed. Conditions were most favorable for the feeding of the crop in this way as the weather was dry and there was practically no waste. I took a basket and went over the patch a few days after turning the hogs out and got less than a bushel of corn from what remained standing."

(Also Printed as Bulletin 105 of this Station.)

THE IMPORTANCE OF THE STUDY OF ENTOMOLOGY; HOW TO COLLECT AND PRESERVE INSECTS.

F. L. WASHBURN, M. A., Entomologist.

"The natural resources of the territory of the United States were at the time of its settlement richer and more varied than those of any other equal area upon the surface of the earth. The development of these resources has given us an increase in population and wealth undreamed of by the men who founded our government, and without parallel in history. It is obvious that the prosperity which we now enjoy rests directly upon these resources. Their conservation is the most weighty question now before the people of the United States."

[*Extract from President Roosevelt's letter to the Governors of all the States.*]

The Relation of Insects to the Nation's Wealth:

Entomology means the study of insects. Not many years ago an entomologist was looked upon as a harmless non-utilitarian, and the word called to mind the picture of a spectacled and bearded lunatic, wildly waving an insect net and pursuing a flitting butterfly over field and bog. Even now amongst many of our people the word is synonymous with "bug hunter," an individual who collects, kills, pins, classifies and labels what the public broadly characterizes as "bugs," said individual adding not a jot or tittle to the world's income, a dilitante who in no way benefits mankind.

Of late years the science of entomology is being everywhere recognized as of great practical importance. We need only to refer to a few facts to emphasize the terrible destruction caused by insect pests alone, havoc which is rated by the millions of dollars, and to mention certain appropriations made of late years to forward the work of entomology, to show the important part

played in our economics by insects, and the appreciation of the work of entomologists as shown by substantial assistance rendered them by Congress, state legislatures, and the various state institutions where the science is made an important feature of the work.

The average total monetary value of all of the farm products of the United States each year, based upon Government reports, is approxmiately six billion, seven hundred and ninety-four millions of dollars ($6,794,000,000). Our forestry products will average about $600,000,000 annually. This added to our agricultural products makes a grand total of $7,394,000,000. Loss through insect ravages for one year in the United States, from estimates made by the Department of Agriculture, has been found to be represented by the enormous sum of eight hundred millions of dollars ($800,000,000), nearly one-ninth *of the total agricultural and forestry output*, represented by the darkened portion in the accompanying illustration, Fig. 1. In other words eight hundred millions of dollars might be added yearly to our agricultural and forestry output if we could eliminate the work of injurious insects.

Fig. 1.

This does not include the annual loss of human life through the agency of insects. We now know that malaria owes its existence in the human system to the agency of a mosquito; that another mosquito transmits the deadly germ of yellow fever, and that the filthy house fly, altogether too common in our homes, may be, under certain conditions, the means of conveying the germ of typhoid from filth to articles of food. In fact, it has been well, and we believe, truthfully said that during the Spanish-

American War, we lost but three hundred men by bullets, but five thousand through the agency of house flies, owing to grossly unsanitary conditions in some of our camps. The courts apparently regard a human life as worth $5,000; on that rather sordid basis the United States lost at that time, within the confines of a few camps, and by the work of the filthy fly, a producing agency worth to the country, at the lowest estimate, twenty-five million dollars; as a matter of fact it would probably average very much more.

Just as Fig. 1 shows the average yearly productions of the United States from agricultural and forest sources, the shaded area representing that portion of the yearly output which is sacrificed annually to insects, we make use of the following figures to show the proportions between the estimated average value of some of the more important agricultural products of the United States, and the value of that part which, in each case, is annually destroyed by insects. As shown by the shaded areas, Fig. 2 illustrates the fact that, although we estimate (1906) our annual wheat crop as worth $450,000,000, we lose yearly from ravages caused by insects $100,000,000, or over 20 per cent of the total output. Of this amount the Hessian fly is yearly responsible for $20,000,000 or over, the Chinch bug gets away with $15,000,000 and the balance is sacrificed to locusts, grasshoppers, joint worms, wire worms, cut worms, army worms, etc. Our corn output in 1904, Fig. 3, was estimated at $1,000,000,000 (the 1906 estimate shows an increase of about $100,000,000), but each year the corn root worm takes $20,000,000 from this crop, the boll worm the same, and the chinch

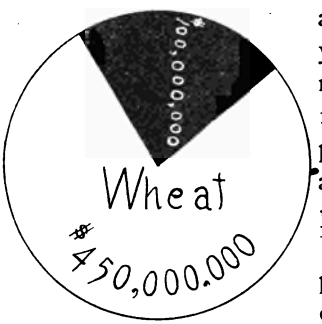


Fig. 2.

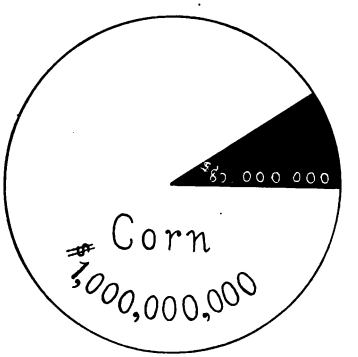


Fig. 3.

bug the same, while wire worms, cut worms, army worms, white grubs, stalk borers and others destroy together $20,000,000 worth, making the yearly insect tax on corn $80,000,000.

Turning to the hay crop, Fig. 4, the 1906 estimate claims $600,000,000 as a fair representation of the product, but at least $60,000,000 or 10 per cent of this amount is levied on this annually by locusts, grasshoppers, army worms, cut worms, grub worms, leaf hoppers, wire worms, "leather jackets," etc.

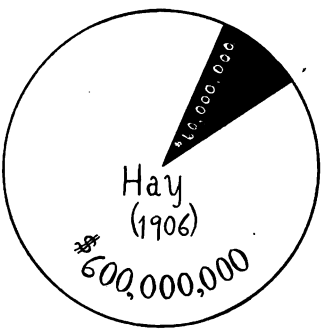


Fig. 4.

One hundred and thirty-five million dollars ($135,000,000) represents pretty closely the value of our annual fruit crop, but different scale insects (notably the San Jose Scale), codling moths, curculios, borers, and the host of caterpillars which infest leaf and fruit, rob us yearly of 20 per cent of what belongs to us, about $27,000,000, Fig. 5. Of potatoes we annually produce a crop worth in the aggregate $150,000,000 (1906), but we lose by insects each year on this crop alone nearly or quite $30,000,000, see Fig. 6. Our animal products, will easily represent $1,750,000,000, but 10 per cent of that amount, Fig. 7, or $175,000,000, goes each year to satisfy various insect parasites.

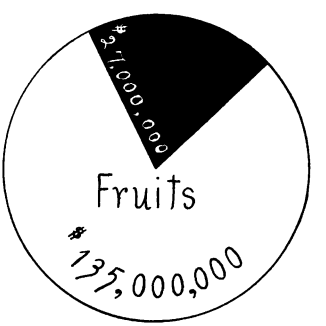


Fig. 5.

The planted forests or wooded areas of our farms, worth perhaps $200,000,000, suffer an annual loss of 10 per cent at the mouths of insects; while our natural forests lose each year $70,000,000 through the same agency. Think of 600,000,000 feet of good timber in a limited area in the Black Hills, representing a cash value of over $25,000,000, being destroyed by insects in one year! This actually happened in 1902. See Plate I.

It must be borne in mind that all of our references have been to insect damage alone, no record having been made in this publication of the immense additional loss occasioned by plant diseases, rust, blight, rot, mildews, etc.

It is the work of the economic entomologists to endeavor to restore to the agricultural classes each year as much as possible from the loss occasioned by insects, represented by the figures above given, and by their researches to place people on their guard against insects known to be a menace to human life. That they are reasonably successful in this is shown not only by the references in the following paragraphs, but by a hundred or more other facts which are matters of statistics, and on record where they can be easily referred to.

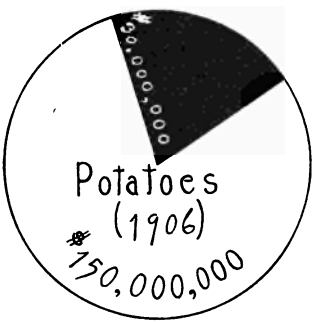


Fig. 6.

The case of the Gipsy Moth alone serves to illustrate the grave danger from a neglected pest, and the importance of thorough work by trained experts. Imported in 1868, and escaping from the original importer, Trouvelet, of Medford, Mass., it gradually increased until in 1890 the state saw the necessity of organizing a campaign against it. Had its increase been appreciated and checked, which might have been done with a small expenditure of money previous to 1875, it would not have become a prominent feature in our financial history, but so firm a hold had it obtained, and so prolific was it that by 1900 Massachusetts had expended over a million of dollars in a losing fight against it.

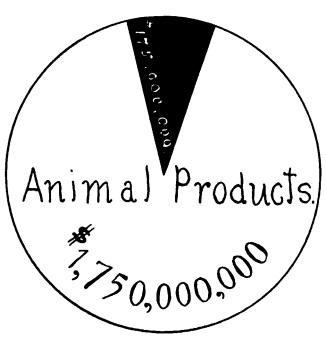


Fig. 7.

Now, as evidence of its appreciation of the practical work of Economic Entomology, a Gipsy Moth Commission, with an annual appropriation of $150,000 is maintained by the state to fight

this pest; private citizens are spending approximately about $100,000, and towns and cities nearly $100,000. As an aid in the struggle the United States Government helps by appropriating $10,000 for the importation of parasites which prey upon this pest in Europe.

The state of New Jersey has appropriated $350,000 each year, or as much of that sum as is necessary, for work against mosquitoes alone.

The South has lost annually $12,000,000 in its cotton raising area, through the work of the Cotton Boll Weevil, and in 1904 in Texas alone about $22,000,000 was sacrificed to this insect. Field work by trained entomologists has shown means of preventing a large proportion of this loss.

The Hessian Fly, Plate IV, has, at times, until made a special study levied an annual tax upon our wheat of from $100,000,000 to $200,000,000, while the Codling Moth, until remedies were found for it by entomologists, destroyed each year at least $10,000,000 worth of apples in the United States. The corn root worm took nearly or quite $100,000,000 each year out of the Mississippi Valley, until entomologists found the proper means to combat it.

The value of stored products, such as mill stuffs, fruit, cotton, woolen and other manufactured goods, has, in the past, depreciated annually $100,000,000 by insect attack, but entomologists have found that expert fumigation with hydrocyanic acid gas, or bisulphide of carbon, will reduce that nearly or quite one-half. Within the last eight years, state and government entomologists have learned practical methods of combating our most destructive fruit insect, namely, the San Jose Scale, so that growers putting the proper methods into practice, need no longer fear it. This saving, both to tree and fruit, directly traceable to the work of entomologists, amounts to millions of dollars.

It is a significant fact that at the last annual meeting of the American Association for the Advancement of Science, held in Chicago in December, 1907, and January, 1908, during an address of welcome to the visiting scientists given on behalf of the faculty of the University of Chicago, the speaker, in emphasizing the

triumphs of science in recent years, took *three out of his five total illustrations from the field of economic entomology.*

It is to this practical and inviting field of work that we invite students. Such a study may well be begun by a school boy or school girl who has the taste for it, in an amateurish way, and in the following pages, intended primarily as directions for students in the Minnesota State Agricultural College and School, are given sufficiently complete directions for collecting and preserving insects, in the hope that the suggestions therein contained will not only lead some of our younger citizens into an employment which is a bread and butter making proposition, but will encourage, perhaps, a larger number in a study which is of itself fascinating, quite apart from its practical bearings.

An Economic Entomologist, to be a success in his field, which is by nature an intensely practical one, has to eschew the writing of books. The moment he yields to the temptation of being an author, a "professional author" let us say, and falls into the ruts followed by book makers, so much time and energy is consumed in this that little is left for what his position calls for, and he ceases to be a successful specialist.

HOW TO COLLECT AND PRESERVE INSECTS FOR STUDY

What is an Insect?

One Branch or Phylum of the Animal Kingdom is called *Arthropoda* ("jointed-footed") and includes all animals without a backbone, which have segmented bodies, the body segments bearing jointed appendages of various kinds. Some of these animals live in water or moist places, are covered with a limy crust, and are called *Crustacea,* the crayfish, lobster and crab, and barnacles, for example. All the other sub-groups or Classes under this Phylum live on land, when adult. But some are worm-like, with many legs, the centipeds and millipeds, Class *Myriapoda;* and some have the head and thorax (second division of the body) in one piece, and have in the adult stage eight legs. This group includes the scorpions, mites, ticks and spiders. Finally, the Class *Insecta* or *Hexapoda* ("six-legged") includes all the insects, and

if we were asked to give in a brief way the characteristics which would include *all* insects, and exclude all other animals, we would say: *Insects are Arthropods, which in the adult stage have six legs and no more; they breathe air directly through a system of tubes (tracheæ) opening on the surface. In their life history they pass through, from the egg stage to the adult, more or less changes or metamorphoses; they have one pair of antennæ (feelers), two compound eyes, and frequently one or more simple eyes. They generally have wings in the adult stage.* See Fig. 8.

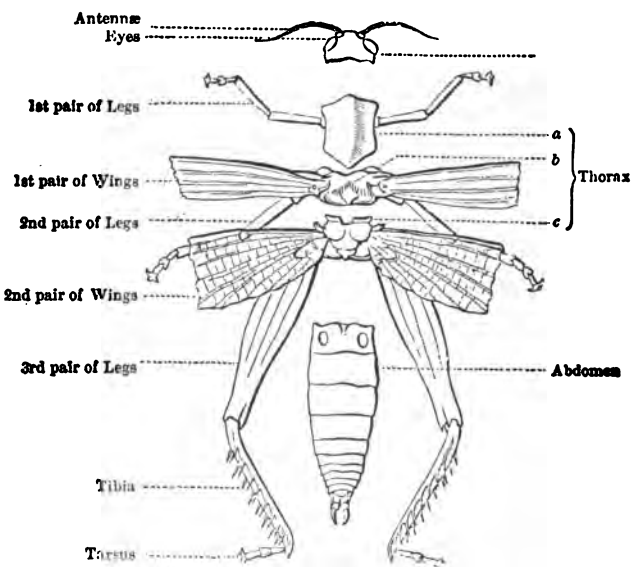


Fig. 8. Dissection of a locust or "grasshopper" to show divisions of the body.

It will be seen from the above that neither a spider, nor a tick is an insect. In looking over this enormous class, comprising at least four-fifths of all known species of animals, we note that there are some great differences between them; a squash bug is widely different from a butterfly, though agreeing with it in the above general characteristics, and a beetle does not resemble a mosquito. Hence the class is divided into a number of groups called Orders, about nineteen. We do not propose to discuss all of these orders here, since it fulfils the require-

ments of this publication to mention the leading ones only. The stages of an insect's life are commonly the egg stage, the larval stage, the pupal or resting stage, and the adult or imago. In insects without a complete metamorphosis, the larval and pupal stages are both active, and frequently referred to as the nymphal stage, or "the nymph."

Fig. 9. May-fly, nymph and imago.

Order *Ephemerida*: This includes the delicate May flies so abundant in spring and early summer. They have four delicate wings, and live but a short time as adults. The young stage, nymph stage, is found in the water, Fig. 9.

Order *Neuroptera:* This group is characterized by the presence of four delicately veined wings. Representatives of the order are the Golden-eyed Lace-winged fly, whose larva consumes plant lice, and the "ant-lion" whose larva digs pits in sandy soil, wherein it lies in wait for other insects, Fig. 10.

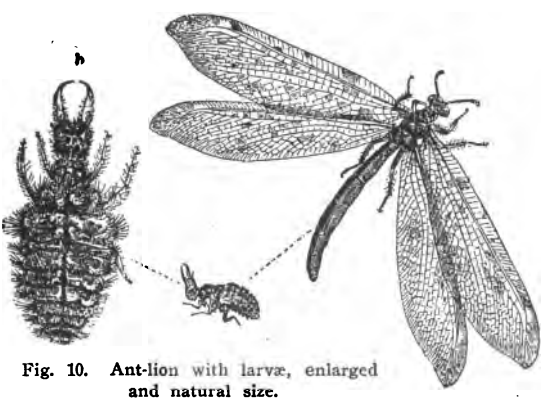


Fig. 10. Ant-lion with larvæ, enlarged and natural size.

Order *Odonata*: The Dragon flies and Damsel flies, with four wings of nearly equal size, biting mouth parts, and large

compound eyes. The larval or nymph stage is passed in the water, Fig. 11.

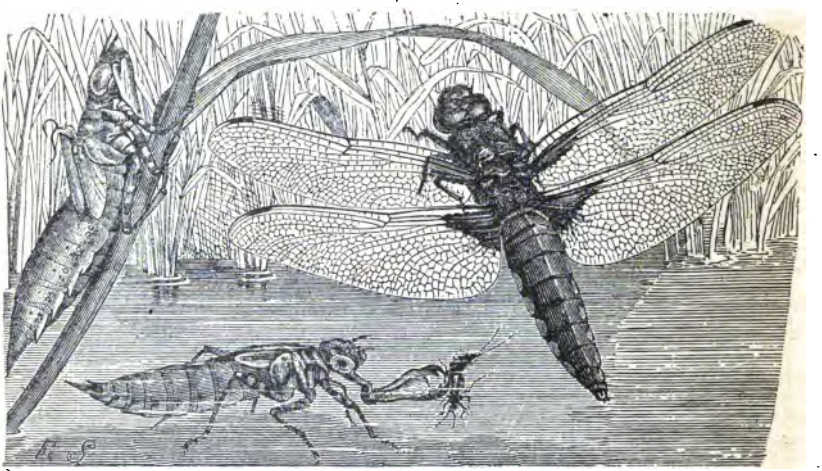


Fig. 11. Dragon-fly with nymph and pupal skin.

Order *Orthoptera* ("straight-winged"): Here occur the locusts, which we commonly call grasshoppers, Fig. 12, the true

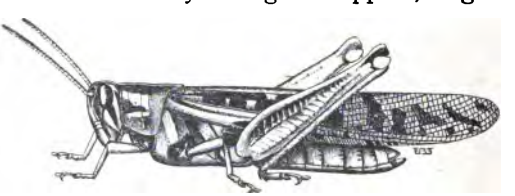


Fig. 12. A Locust.

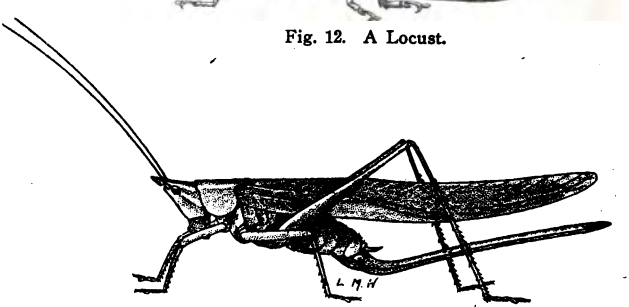


Fig. 13. A true Grasshopper.

grasshoppers, Fig. 13, and katy-dids, Fig. 14; crickets, "walking sticks," Fig. 15, and cockroaches. These insects have, for the

most part, four wings, the foremost pair being really wing covers, or *tegmina;* the second pair are thin and gauzy, mouth parts formed for biting, metamorphosis incomplete. The grasshoppers, locusts, crickets and katy-dids have hind legs adapted for jumping.

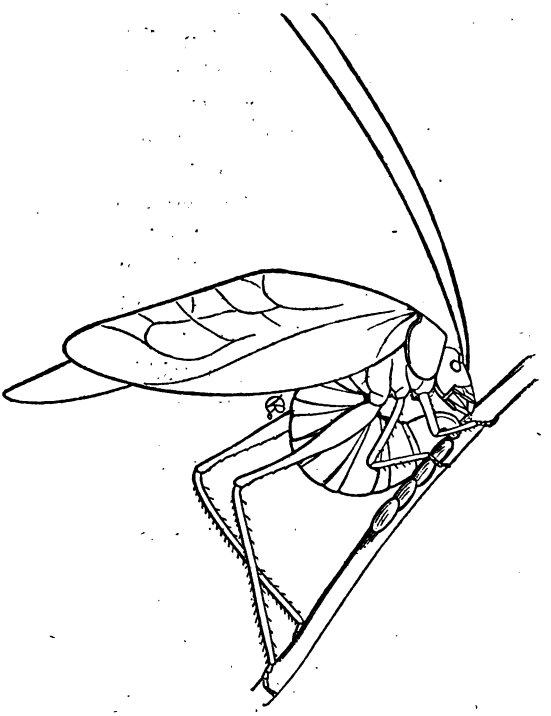


Fig. 14. A Katydid ovipositing. After Riley.

This order is at times very injurious, the Rocky Mountain locust or grasshopper, which normally lays its eggs on the slopes of the Rockies, frequently breeds on the plains east of there, and has at times swept down upon Kansas, Nebraska, Dakota, Minnesota and other states, leaving no living plant behind it. Locusts and grasshoppers lay their eggs in the soil, and fall plowing generally serves to keep our native forms in check.

Order *Hemiptera:* This order includes all the plant lice, the true parasitic lice, all the scale insects, and the true bugs, see Fig. 17, and Plates II and III. The name Hemiptera, which means "half-winged," is given the entire order because the anterior half of the first pair of wings in the true bugs is thickened, only the posterior part being wing-like. The mouth parts are formed for sucking, and they have an incomplete metamorphosis. This is probably our most destructive order, for here occur scale insects, plant lice, leaf hoppers and

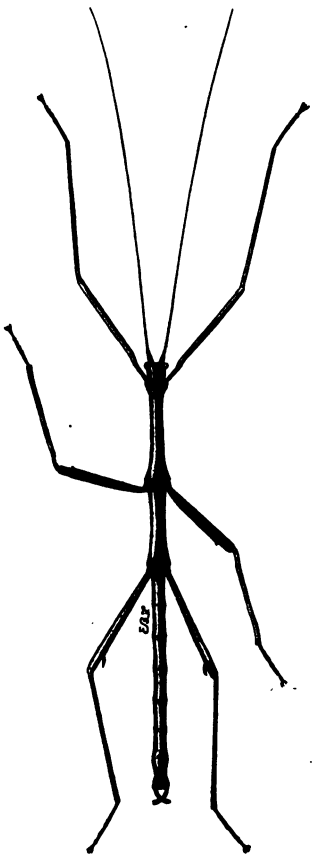


Fig. 15. A Walking-stick.

tree hoppers, squash bugs, Cicadids or harvest flies, and the true lice which affect man and animals. It is interesting to note that the word "bug," which is frequently employed to designate any insect, is rightfully only applied to that division of the Hemiptera which are "half-winged."

Order *Diptera* ("two-winged"): These are the true flies, such as the house fly, mosquito, horse flies, etc., characterized by the possession of only two wings, the second pair being represented by a pair of small knobbed projections, the halteres or balancers; they have mouth parts adapted for sucking, lapping or stabbing. They have a complete metamorphosis, the larva being referred to as a maggot, and the pupa or resting stage is enclosed in a brown skin called a *puparium.* Fig. 18 will illustrate a type of the order.

Order *Siphonaptera:* Wingless, degraded insects. A complete metamorphosis and mouth parts adapted for sucking. Here occur the dog and cat flea, human flea and others.

Order *Coleoptera* (*"sheath-winged"*): This name refers to the fact that the insects of this group have the fore wings hardened and horny, or modified to form covers for the second pair of wings, the true wings, when they are present. Biting mouth parts and a complete metamorphosis are

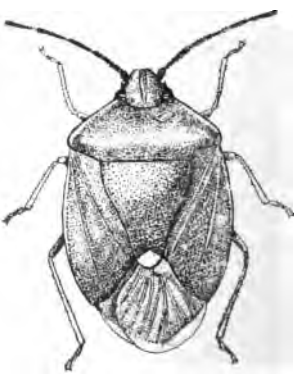


Fig. 17. A true Bug.

Fig. 18. House Fly. Original.

further characteristics of this group, which includes the beetles. The potato beetle ("potato bug"), most of our wood borers, the beetle which comes from the white grub, blister beetles, plum curculio, weevils, and many others occur here. See Figs. 19 and 20.

Order *Lepidoptera* ("scale-winged"): The butterflies, moths and skippers are characterized by the presence of four wings, covered with tiny scales, which easily rub off if the insect is handled roughly. Their mouth parts are modified for sucking, and they have a complete metamorphosis. The larva is spoken of as a "caterpillar," and tent caterpillars and cut worms are familiar objects in the country. The moths are generally, but not always, night fliers; their antennæ are usually either thread-like or feather-like. When at rest they rarely hold their wings elevated as do butterflies. The skippers are day fliers, and dart rapidly from place to place. Butterflies are day fliers; their antennæ or feelers are

Fig. 19. A Ground Beetle. Ruggles.

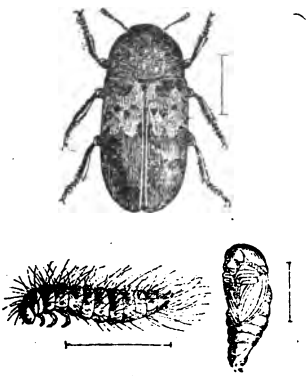


Fig. 20. The Larder Beetle, with larva and pupa.

thread-like, and with a knob on the end. Injurious forms in this order are the Codling Moth, Figs. 21 and 22; cut worm moths, currant borer, cut worms and army worms, and others. The pupal stage of butterflies is naked and called a "chrysalis," Fig. 23.

Order *Hymenoptera* ("membrane-winged"): This group of insects has four membranous wings with but few veins therein. The front wings are the larger. Mouth parts adapted for biting and sucking. The abdomen of the female is usually furnished with a sting, piercer or "saw." The metamorphosis is complete. Fig. 24.

The honey bee is a good example of this order, which also includes the true ants, the wasps, hornets and sawflies. A large number of parasites which attack injurious forms of insects are also found here.

Fig. 21. Codling Moth, twice enlarged. Original.

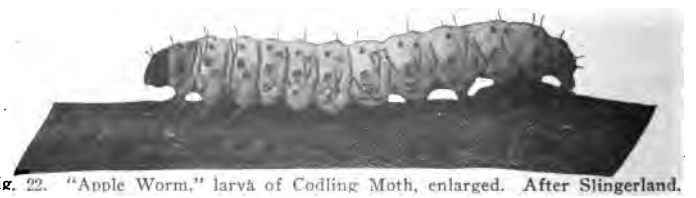


Fig. 22. "Apple Worm," larva of Codling Moth, enlarged. After Slingerland.

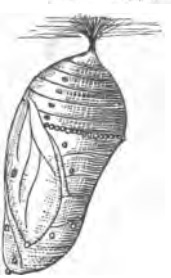
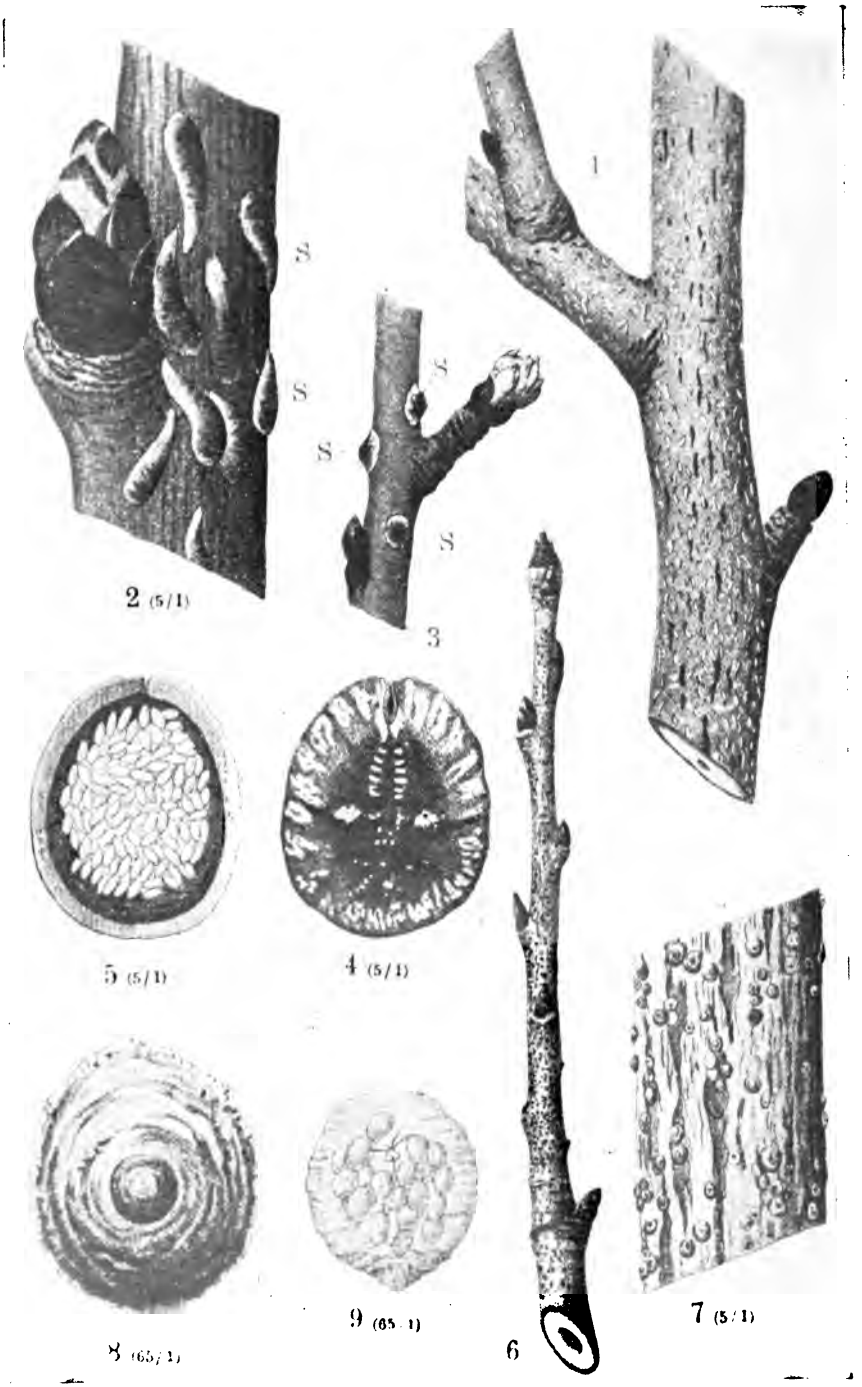


Fig. 23. A Chrysalis. After Riley.

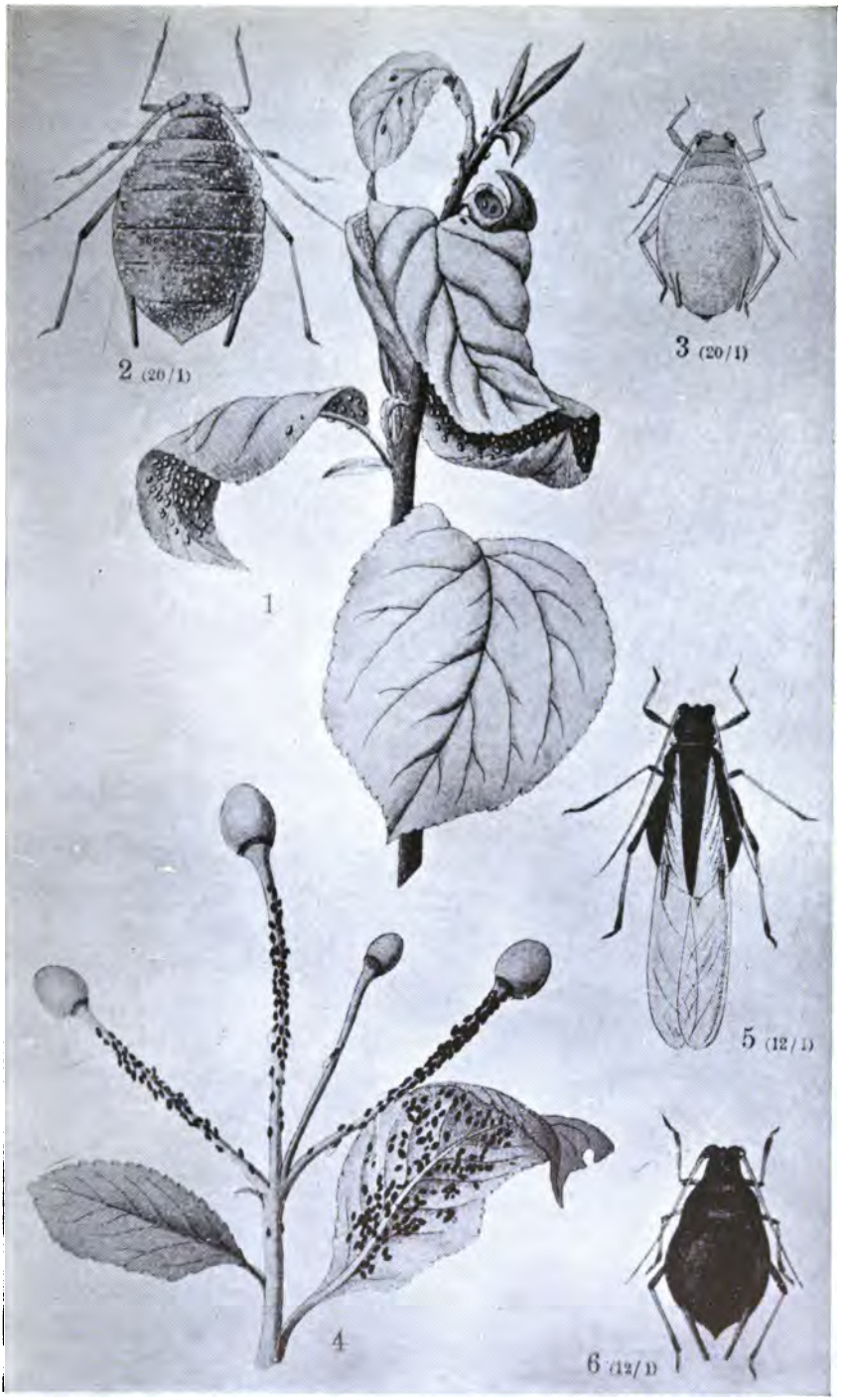
The young collector has probably provided himself or herself with some insect pins and some sheet cork, which can be purchased for a small sum from retail dealers, though he can substitute slices of cork stoppers for his sheet cork, or pith from corn stalks, at no expense whatever, gluing the same to the bottom of a cigar box. Good insect pins of various sizes he can hardly get along without if he purposes to pin his specimens. The late spring and sum-

Plate I. Our Forests invite inscct attack. Over two million feet of timber, it is claimed, has already been killed in the Black Hills Forest Reserve, by a single species of beetle. *Dendroctonus ponderosae,* Hopk. Original.



SCALE INSECTS

Plate II. Fig. 1, Oyster Shell scale on apple. Fig. 2, same enlarged 5 times. **Figs. 3, 4, 5,** Lecanium scales, natural size and enlarged, Fig. 5 showing eggs from below. Figs. 6, 7, 8, 9, San Jose Scale, natural size and enlarged. Fig. 9, the female with scale removed. After Kirchner & Boltshauser.



PLANT LICE

Plate III. Two different species of plant lice, one affecting the apple; the other the cherry. After Kirchner & Boltshauser.

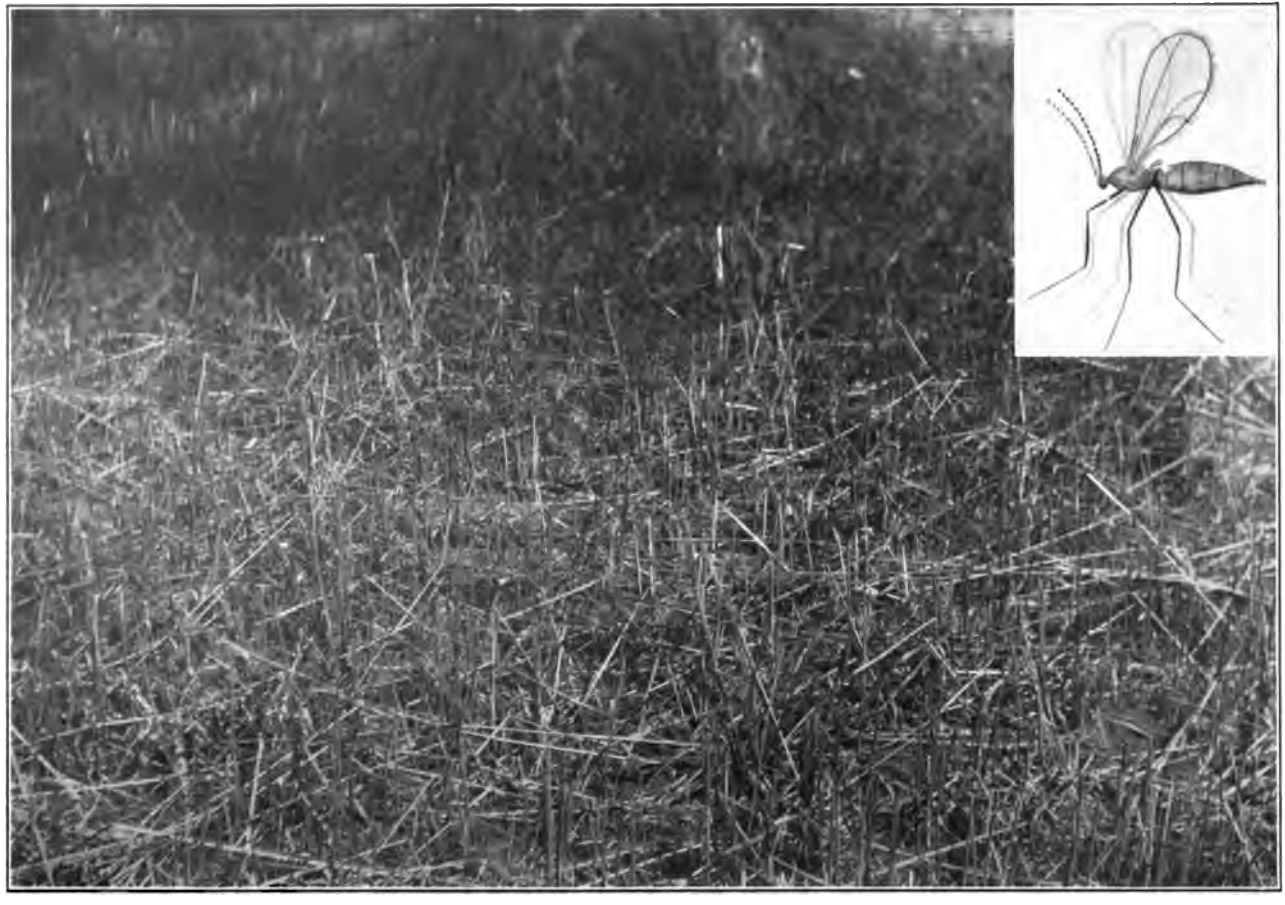


Plate IV. A portion of a Minnesota wheat field badly "down" as a result of the work of the Hessian Fly, a tiny insect about one-tenth of an inch long, shown enlarged in the upper right hand corner. Original.

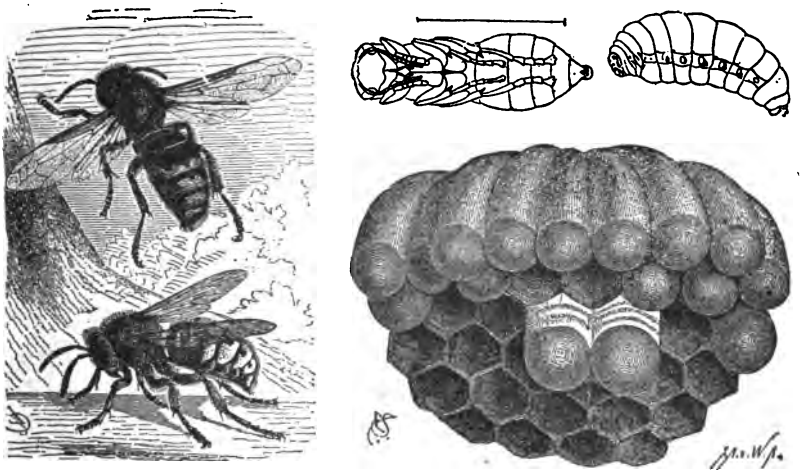


Fig. 24. Hornets, all stages, and cells.

mer months naturally offer the best opportunities for collecting.

When he goes into the field he should take a good insect net, one or two cyanide bottles, a few vials for holding delicate insects (some of the vials half full of alcohol for killing larvæ), and some paper pill boxes, or tin salve boxes. These and the vials will hold living larvæ, which the collector may desire to take home. A pair of forceps, Fig. 25, is not necessary, but sometimes very convenient in handling very small insects and those that sting. A box (cigar box will do) and some envelopes or folded papers are desirable to safely hold butterflies with wings folded, until the return home.

Fig. 25.

Fig. 27.

A cyanide bottle, Fig. 27, is made by placing two or three small pieces of cyanide of potassium, pieces to be a little bigger than a pea, or one large piece, in the bottom of a large-mouthed vial, and covering the same with plaster of Paris, to

which water has first been added. This mixture should be of such consistency that it will just pour into the bottle, covering the cyanide half an inch. Leave the bottle open a few hours until the plaster is set. If liquid gathers on the top of the plaster, dust in more dry plaster, and later a piece of blotting paper can be placed over the plaster to absorb moisture, and occasionally removed. As cyanide of potash is deadly poison, it is well to put the word "POISON" on the bottle. A tight cork should be provided, and care should be taken not to leave the bottle open, after it is in use, for any length of time, lest it should lose its strength. A very useful style of bottle is shown in Fig. 28. This is provided at one end with a metal cap, which can be removed, and either cyanide or chloroform placed on cotton in the lower end. A small straight-side vial made into a cyanide bottle is useful for very small insects, and takes up but little room in the pocket. In fact, one should take more than one cyanide bottle into the field to forestall any accident which might befall one, and to have one to use before insects are dead in the other. It is well to leave specimens, except delicate moths, over night in the cyanide bottle, or at least for several hours. Strips of paper in a cyanide bottle prevent undue rattling about of insects, and serve to absorb moisture which would ruin specimens.

Fig. 28.

A serviceable net can be made out of mosquito bar (or better, of bobbinet), strung on a wire hoop fastened to a pole about five feet long. It is a very good plan to fasten a narrow strip of cloth to the wire hoop, and sew the net to that. Better nets and jointed poles can be purchased. Fig. 29 shows a folding net, which can be packed in a small space. Personally, we prefer a net which tapers considerably, but not to a point. Some insects are best caught when they are on the wing; others should be allowed to alight. A quick pass is made with the net, forcing the butterfly or moth, or grasshopper, as the case may be, to

the bottom, and a turn of the wrist folds the net upon itself, preventing the captive from escaping. In sweeping for grass or clover insects, the net is passed back and forth as one walks along, striking the tops of the plants, and by its continued and rapid motion the captured specimens are kept safely in the bot-

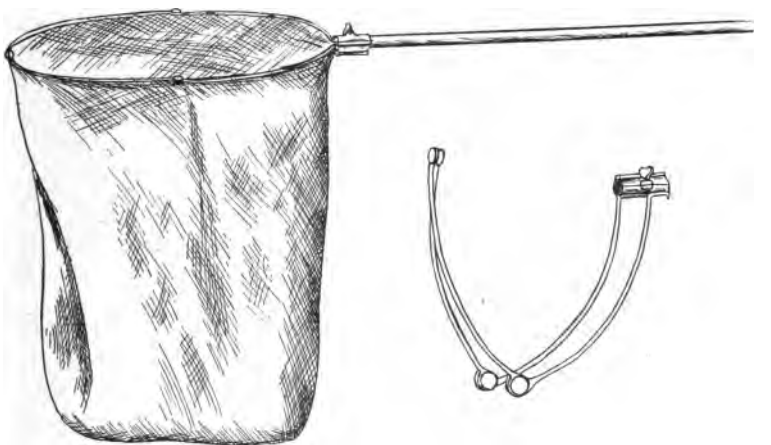


Fig. 29.

tom of the net until the collector stops, when a rapid turn doubles the net, and holds all the contained insects securely. In beating brush or shrubbery a "beating net," made of stout cloth, is used.

The writer sometimes lulls stinging insects to unconsciousness by placing the point of the net in the bottle, and holding the cork over the mouth for a minute, when the bee or wasp can be taken out safely, and dropped into the killing bottle to complete the operation. Butterflies and moths should not be permitted to flutter about in a cyanide bottle, thus denuding the wings of their beautiful scales. They may be pinched between thumb and finger while still in the net (see Fig 30) or, a drop of chloroform may be placed on the head and thorax, and then the insects transferred to the cyanide bottle. Plant lice are best killed by dropping into vials of alchohol.

Fig. 30. After Holland.

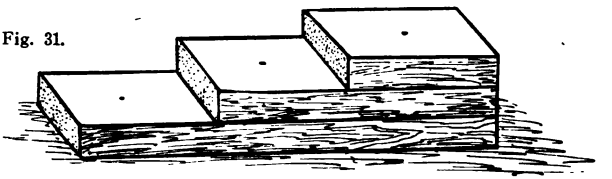
Some insects may be knocked off of shrubbery or branches of trees by jarring, the net being held below. Water insects, such as "water boatmen," skippers, and "whirligig-beetles" can be captured by using the net. Some larvæ can be found under stones, in ponds and streams. Those that frequent the bottom can be obtained by the use of a metal sieve-scoop, transferring the material—small sticks, mud, leaves, etc.—to a jar, whence the specimens can be separated later.

Insects of various kinds are found in a host of localities, upon flowers, upon shrubbery, along the edges of woods in the woods themselves, in pastures and meadows, along the banks of streams, lakes and ponds and in the waters of the same; in rotten logs and stumps, under logs and rubbish, under bark, in fruits, and in nuts, etc. The collector who has the keenest eyes, is the one, other things being equal, most likely to succeed.

Baiting and Night Collecting: While broad daylight and bright sunshine are the best conditions under which to collect the majority of insects, many are best collected at twilight, and night collecting by the use of baits is fascinating. An acceptable bait is made of brown sugar and water, forming quite a thick syrup, and adding a goodly amount of stale beer or rum; put this on say twenty trees (it may also be used on fences or stumps) in the woods, just after sundown, spreading it on with a brush over a space about three by eight inches, and noting carefully the baited trees, so that they can be found in the dark. If you start out between nine and ten with a lantern, preferably a dark lantern, and several cyanide bottles, and visit the treated trees, flashing your light carefully on the anointed portions, you will probably discover moths and other insects at work sipping the, to them, attractive mixture. A collecting bottle is placed cautiously over one of these insects and moved to right or left slightly, thus loosening the insect from its hold, whereupon it falls into the bottle, the latter is tipped up quickly and corked, placed in one's pocket, and a second bottle used for another insect. These insects are later united in one bottle, leaving one or more bottles free for use in capturing. Warm, still nights are best suited for this work. Lights in an open window, or better still, the electric lights in the streets of our towns and cities offer excellent opportunities for night collecting.

Pinning, Spreading, Inflating, Labeling, etc.: In pinning insects a Comstock spacing block will be found useful. Its construction is easily understood by a glance at Fig. 31. Each

Fig. 31.



layer from which the block is made is one-fourth as thick as an insect pin is long. The hole on each step is large enough to admit the head of the pin. Each insect should be, when pinned, just one-fourth of the length of the pin from the head. This is brought about by inserting the head of the pin, after the pin has been pushed through the insect, into the hole of the lower step,—the back of the specimen should rest on the step. By reversing the pin, and using the first and second steps the proper spacing of labels is secured, and when small insects are mounted on points, the hole in the highest step receives the point of the pin. The German insect pins appear to be the best, and are made in several sizes. Perhaps sizes 0, 1, 3, 5 and 9 would be those most commonly used by the amateur collector. The thing to be sought is uniformity in height of insects and labels in the box, that the collection may present a neat appearance.

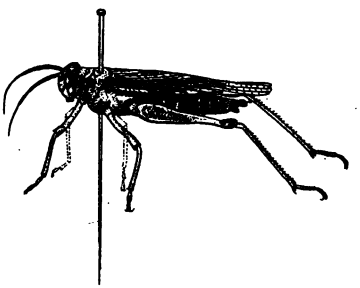


Fig. 32. Original.

Fig. 33. Original.

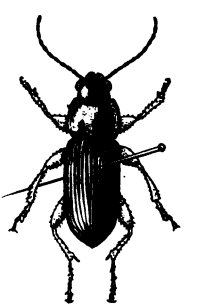


Fig. 34. Original.

Grasshoppers, bees and flies, butterflies and moths, etc., are pinned through the thorax, as shown in Figs. 32 and 33. Beetles are pinned through the right elytron, or wing cover, as shown in Fig. 34. Bugs are pinned

through the median point of the scutellum, Figs. 35 and 35a. Butterflies and moths should be spread on a spreading board, Fig. 36 (which illustration shows the structure of the same, and the position in which the wings are spread), and transferred to the collection when dried. Frequently the wings of other insects are spread if a collector has time to go into such niceties. Two dissecting needles, made by pushing the blunt ends of needles into round sticks 4 in. long, of the diameter of lead pencils, will be found useful tools in spreading. Small moths, and also other small insects are sometimes mounted on pith, by the use of tiny wire, the pith being first fastened to an insect pin at proper height, Fig. 37. Again, a small beetle or fly, or other insect, may be mounted by being gummed to a cardboard point, as shown in Fig. 38. These points are made with a triangle punch illustrated in Fig. 39. Pinning forceps are desirable accessories in order to hold the pin upright, and to keep it from bending when it is being forced into the cork bottom of the collection box. Figs. 40 and 41 represent these forceps, the first used with lighter

Fig. 35. Original.

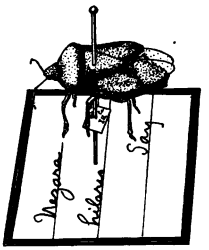


Fig. 35a. Original.

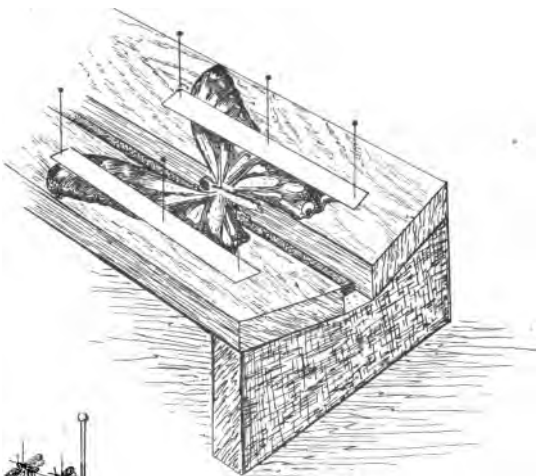


Fig. 36.

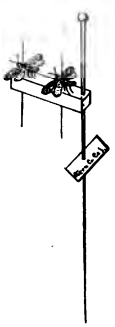


Fig. 37. Original.

Fig. 38.

pins, and the latter where large butterflies, etc., are being placed in position in the collection. A cheap pair of pliers will answer

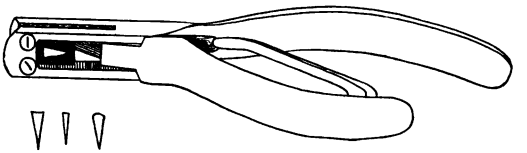


Fig. 39.

Fig. 40.

fairly well if one does not care to go to the expense of the regulation forceps. Very delicate insects, such as plant lice, minute flies, etc., which have first been in 90 per cent alcohol, are frequently mounted on glass slides, with appropriate labels, Fig. 42, for identification and study with the microscope.

In studying and handling small insects a watchmaker's glass, Fig. 43, is sometimes quite useful. This lies in the fact that it can be held in one eye, leaving the hands free. A pocket lens, Fig. 43a, of some kind is useful.

Fig. 41.

Fig. 44 illustrates a home-made rack for

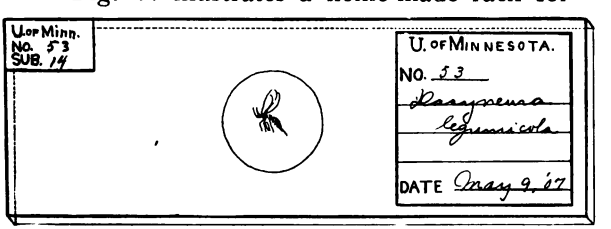


Fig. 42.

Fig. 43.

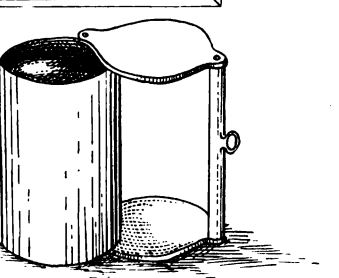


Fig. 43a.

holding vials containing alcoholic specimens to be studied, while Fig. 45 shows the Comstock insect bottle, used by many ento-

mologists for the permanent storing of insect larvæ, pupæ, etc.

Inflating and Mounting Caterpillars: Frequently one wishes to preserve a caterpillar in the dry state for mounting by the side of the imago. Kill the specimen in the cyanide bottle; make a small slit with a fine pair of scissors at the extreme posterior end of the caterpillar;* place it on blotting paper, and placing a round pencil upon it just back of the head, roll it backward gently, pressing out the viscera. Care must be taken to move the caterpillar about during this in order to keep the hairs dry. Then insert a straw or a glass tube drawn nearly to a point, about one-fifth of an inch, into the opening. If a straw is used, push a fine pin through the specimen close to the posterior end, and through the straw. This will hold it in place while inflating. If one uses a glass tube, the tube should be held over a flame until the specimen is dried to it at the point of contact. Should there be any openings between the straw or tube and skin of the caterpillar, a drop of glue will seal them. The actual inflating is done by holding the specimen in a warm place for a few moments, keeping it inflated to natural size until dry. This

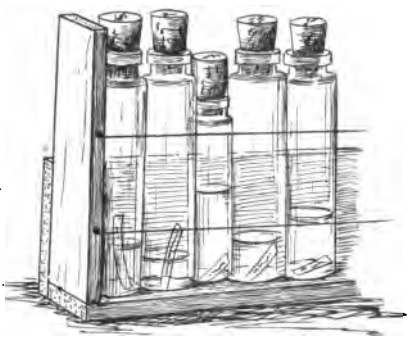


Fig. 44.

Fig. 45.

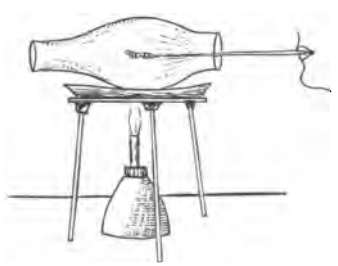


Fig. 46.

* A better way, perhaps, is to insert the point of a pin, about one-eighth of an inch, into the anal opening at the posterior end of the caterpillar and move it carefully around in order to cut through the intestinal wall, thus freeing it from its attachment to the body wall.

may be accomplished by the use of a simple apparatus and one's breath, as shown in Fig. 46, the lamp chimney resting upon an iron saucer filled with sand, or one can purchase an inflating outfit, one of which is illustrated in Fig. 47, in which case the air is forced into the caterpillar from two bulbs. Care must be taken not to scorch the specimen.

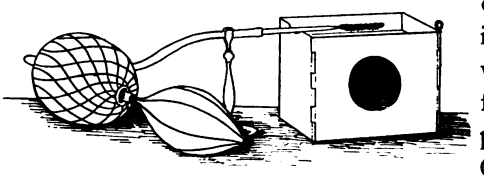


Fig. 47.

When thoroughly dry it may be pushed off the tube with a sharp knife. A mount for the caterpillar has been previously prepared. This will be understood by a glance at the accompanying illustration, Fig. 48, which shows a piece of cork at the proper height on an insect pin, and some fine wire (preferably the covered wire used by milliners) wrapped about it as shown. The two ends are left twisted together, and upon these the caterpillar is thrust, a drop of liquid glue having first been placed on the wires' ends. The specimen is then ready for the label.

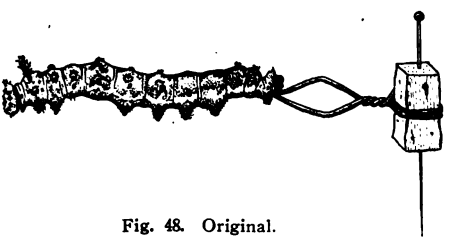


Fig. 48. Original.

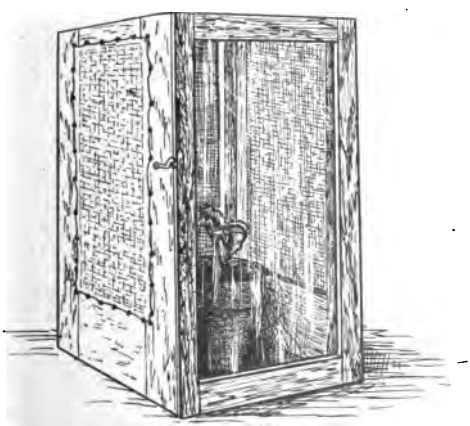


Fig. 49. Original.

Rearing Larvæ: A collector may be uncertain about the identity of a captured larva, or he may wish to procure the imago for his collection, or he may desire to study its life history, observe its moults, etc. This is easily accomplished, whether it be the young stage of butterfly, moth, beetle, fly or bug.

Fig. 50. Original.

The specimen or specimens are confined in some form of breeding jar with an abundance of food. If the food be a plant, a flower pot containing the same may be placed in the cage as shown in Fig. 49, which illustrates a home-made outfit we use in the insectary. Or a lamp chimney, or lantern glass, with cheesecloth over the top, Fig. 50, may be placed over small plant upon which the insect feeds, the glass being pushed into the soil of the pot about an inch. Water insects can be studied in the same way by making an aquarium, as shown in Fig. 51, in which a few water plants are grown, and the water of which is kept fresh. The development of larval stages, wire worms, for example, which infest roots, can be studied in a Comstock root cage, Fig. 52. This, as shown in the illustration, consists of two plates of glass held a short distance apart by a supporting frame. This narrow space is filled with soil, and seeds or young plants placed therein.

Fig. 51.

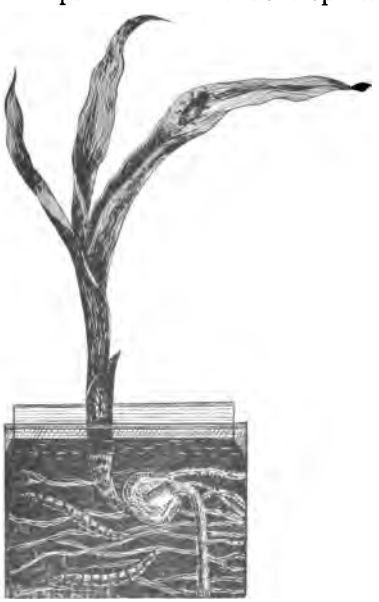


Fig. 52. After Comstock.

Careful and frequent observations should be made of insects in breeding cages, and notes made of dates of capture and condition of specimen, moults, pupation, emergence of imago, etc. Frequently, what appears at the time to be a trivial fact may be an important contribution to the science of entomology; particularly if the specimen be a pest to agriculture.

Any insect which has become dried in storage before being pinned, has to be relaxed before it is handled. We, for years, made use of a relaxing box shown in the accompanying illustration, Fig. 53, and found it very satisfactory. It shows the box and lid in section, *A* marking the point at which the wire gauze forms a false bottom a few inches from the floor of the box. *B* shows surface view of the gauze, the opening in the corner affording an opportunity to pour water into the bottom of the box. A little carbolic acid is placed in this water to prevent

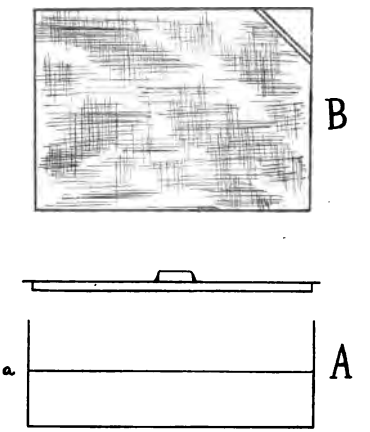


Fig. 53. Original.

Fig. 54. A Schmidt Box. Original.

mold, and insects left on the gauze over night, with the cover on the box, will generally be so relaxed that they can be handled with safety. The box may be made of galvanized iron, and

this particular box is 9 x 14 inches and 5 inches high, the gauze being placed two and one-half inches from bottom.

A tight, dust proof and insect proof box (or boxes) is necessary to hold a permanent collection, and ideal boxes are seen in either the Schmidt box, illustrated in Fig. 54, or in a Comstock box. Collections should be examined every few months to prevent dermestids or other pests from working injury, and if evidence of their presence is observed, the box and its contents should be subjected to the fumes of bisulphide of carbon in a closed receptacle for several hours. Two treatments, with ten days' interval between, may be necessary. Some entomologists keep naphthaline cones, Fig. 55, in their insect boxes as repellants. It is not safe to store insects permanently in unprotected cigar boxes.

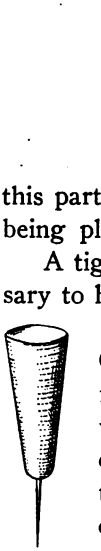


Fig. 55.

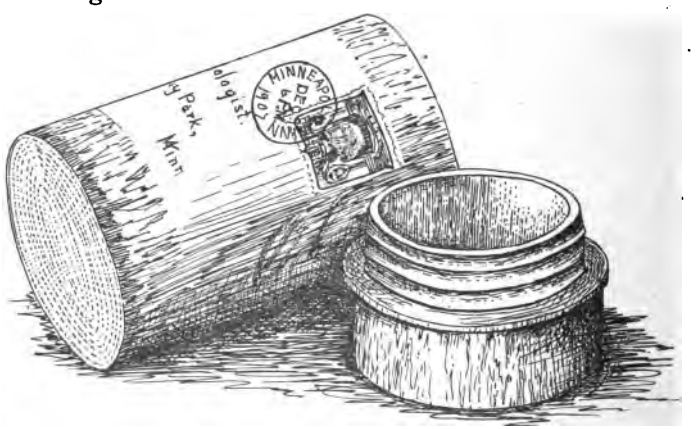


Fig. 56. Original.

In mailing insects in vials, round mailing boxes, Fig. 56, are made use of, the vial being wrapped in cotton. Figs. 57 and 58 show the method of cutting and folding papers for butterflies and moths, either when they are to be mailed (in which case they would be packed flat in boxes), or when they are to be kept in storage. Avoid moisture in packing away insects. and protect them from the attacks of mice and museum pests. Specimens of a miscellaneous nature may be mailed or stored in boxes between layers of cotton, a piece of tissue paper being

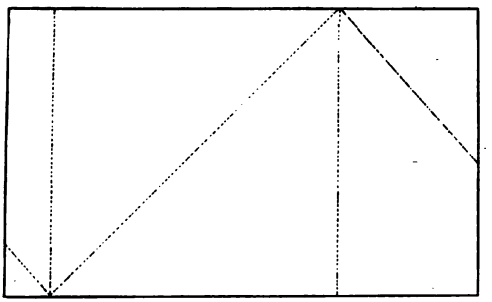


Fig. 57.

placed below and above them to keep them from actual contact with the cotton. This is a good method to be followed by students making small collections, required for a school or college course.

Finally, some form of entomological book-keeping is desirable for any one wishing to make an extended study of the subject. Observations in the field, or in the insectary, can be made upon small sheets of perforated paper, temporaily bound in leather cover of a size suitable for the pocket, care being taken *not* to write an observation upon two or more insects on the same sheet. These

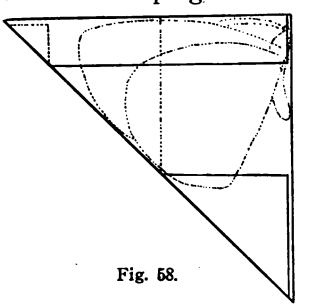


Fig. 58.

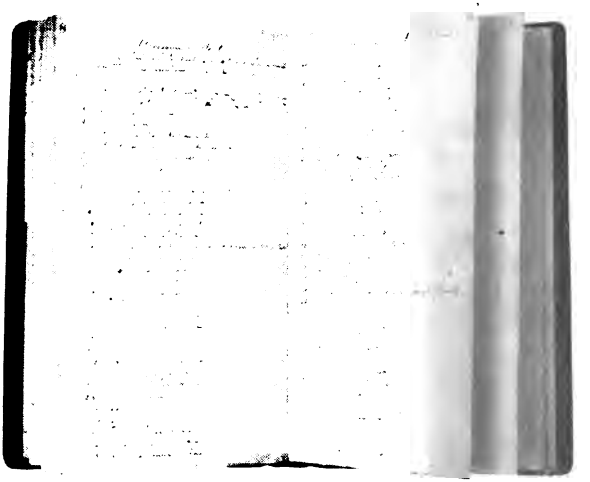


Fig. 59. Accession book. Original.

sheets can later be removed from the temporary cover, and each one filed in a box devoted to a special insect, or a special set of

observations. Accessions to the collection may be entered in a book, Fig. 59, the accession number referring to a special collection or set of insects, and the sub-numbers placed on the side

Fig. 60. Card Index. Original.

referring to the individual specimens in the collection. In this case the insect would bear a label showing its accession number and sub-number, as in Fig. 42.

A card index, Fig. 60, is found to be a very valuable aid, by forming a handy record of literature, illustrations, lantern slides, cuts or special lines of work, and can well be used as an accession index also. The *necessity of having specimens in a collection carefully labeled, and all data where they can be referred to, cannot be too strongly emphasized.*

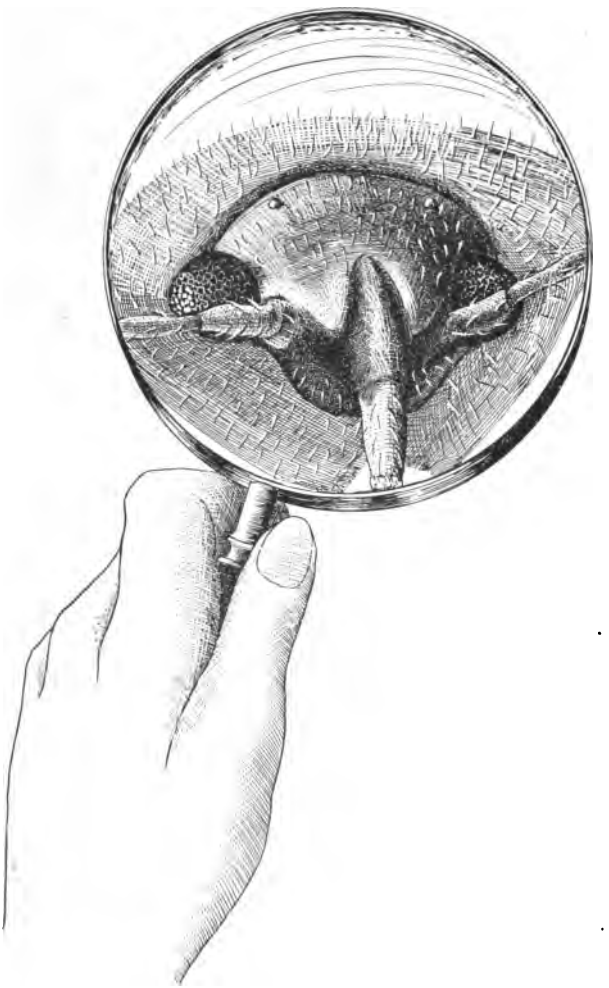


Fig. 61. Don't be afraid to look a Chinch Bug squarely in the face. Original.

Reprint of Bulletin No. 106 of this Station.

THE RELATION OF NUTRIMENT TO PRODUCT.

T. L. HAECKER.

During the summer of 1904, in connection with the World's Fair held in St. Louis, a competitive test in milk production was conducted, in which five Brown Swiss, fifteen Holstein Friesian, twenty-five Jersey and twenty-five Shorthorn cows participated. The different breeds were represented by animals selected by men who were specially interested in them and who knew the conditions of the test. The Superintendents and attendants of the cows of the different breeds were designated by the Associations of the competing breeds, or their representatives. The kind and amount of feed that each cow was to receive was under the control of the Superintendents in charge of the breed, but the weights of the feed consumed and the dairy products yielded were in charge of disinterested officials; who kept a complete record of the kind and amount of feed consumed by each cow, the amount of milk given, its fat and solids not fat content. The Committee was composed of the late Major Henry E. Alvord, Chief of the Dairy Division of the Department of Agriculture; Prof. C. F. Curtis, Dean and Director of the Iowa Agricultural College, and Prof. Farrington, of the University of Wisconsin. The latter was placed in charge of the details and general management of the contest, and discharged the duties with ability and fidelity.

Before the tests began, a list of feeds with prices had been made out and adopted by the parties interested in this work. These valuations were in some cases considered somewhat abnormal, and after a conference of the members of the Experiment Station Commitee with the Chief of the Department of Agriculture, it was decided to issue a new list of feed valuations. The cost of the feed consumed by the cows was, therefore, obtained by using the first set of prices for the first sixty days, and the second for the second sixty days of the test. These two lists of feed valuations are given in the following tables:

TABLE XIX.—Valuation of Forage and Grain.

	Original. First 60 days Ton	Revised. Second 60 days Ton
Timothy Hay	$ 7.50	$ 7.50
Alfalfa Hay	6.50	7.50
Clover Hay	6.00	7.00
Green Peas	3.50	3.50
Cow Peas	3.50	3.50
Clover	3.00	3.00
Cats and Peas mixed	2.50	2.50
Corn Fodder	2.00	2.50
Corn Silage	2.00	2.50
Ground Barley	25.00	25.00
Cotton-seed Meal	25.00	26.00
Linseed Meal, old process	24.00	24.00
Oats, ground	22.00	20.00
Gluten meal	20.00	24.00
Union grains	17.00	20.00
Distillers' grains	17.00	20.00
Gluten feed	16.00	20.00
Corn meal	15.00	20.00
Wheat bran	15.00	18.00
Wheat middlings	15.00	19.00
Hominy feed—corn hearts	12.50	18.00
Brewers' grains	12.00	18.00
Malt sprouts	10.00	18.00
Rolled oats	36.00	36.00

Analyses of Feeding Stuffs.

Two composite samples of most of the feeds used by the different herds were taken during the 120 days of the test. One of these covered the first part of the time, and the other the last part. The samples were taken by adding a small quantity of each feed to a glass jar at feeding time. The first composite sample covered the time up to about August 1st, and the second from August to October.

The analyses of the samples were made by the Bureau of Chemistry of the United States Department of Agriculture, at Washington, D. C.

TABLE XX.—Results of Feed Analyses.

	Water	Ash	Ether Extract	Crude Fibre	Protein	Nitrogen Free Extract
Wheat Bran—						
Brown Swiss, first	16.59	6.47	2.83	11.48	13.41	49.22
Brown Swiss, second	10.57	7.69	3.66	10.60	14.25	53.23
Holstein, second	11.29	7.29	3.78	10.76	13.98	52.90
Jersey, first	13.04	6.17	4.07	9.76	14.76	52.20
Jersey, second	11.16	6.31	3.90	8.15	14.47	56.01
Shorthorn, first	12.86	6.44	5.32	9.26	14.07	52.05
Shorthorn, second	10.21	7.15	3.65	9.96	13.88	55.15
Corn Meal—						
Jersey, first	13.91	1.05	1.89	1.31	7.57	74.27
Jersey, second	14.17	2.00	1.92	1.44	8.25	72.22
Holstein, second	13.50	1.78	2.79	1.88	8.25	71.80

TABLE XX.—Result of Feed Analyses —(Continued.)

	Water	Ash	Ether Extract	Crude Fibre	Protein	Nitrogen Free Extract
Hominy Feed—						
Shorthorn, first	9.25	2.77	8.02	4.48	10.23	65.25
Shorthorn, second	9.57	3.41	6.53	9.40	10.50	60.59
Brown Swiss, first	10.16	3.67	9.10	5.04	9.86	62.17
Brown Swiss, second	8.69	3.23	6.98	7.94	10.25	62.92
Jersey, second	10.69	3.27	5.56	3.65	9.33	67.50
Holstein, second	9.59	2.94	7.00	7.61	9.84	63.02
Gluten Feed						
Brown Swiss, first	10.08	2.16	4.41	6.94	20.79	55.62
Brown Swiss, second	9.56	1.39	2.70	7.35	23.12	55.88
Jersey, first	10.54	2.00	4.42	8.73	23.69	50.62
Jersey, second	9.56	2.71	2.86	4.70	24.08	56.09
Holstein, first	9.91	2.24	4.55	7.07	20.18	56.05
Holstein, second	9.48	2.59	3.51	2.46	23.56	58.40
Shorthorn, first	9.71	1.86	3.20	6.19	25.62	53.42
Shorthorn, second	11.39	4.44	2.49	7.56	23.81	50.31
Cottonseed Meal—						
Brown Swiss, first	10.18	6.77	8.14	7.73	37.43	29.75
Brown Swiss, second	10.34	6.74	8.31	7.57	40.00	27.03
Shorthorn, first	9.81	6.69	9.49	7.29	40.82	25.90
Shorthorn, second	9.32	6.30	12.21	6.29	40.12	25.76
Jersey, first	9.34	5.62	9.38	8.25	42.10	25.31
Jersey, second	9.69	5.05	8.60	7.88	41.25	27.53
Holstein, second	10.44	6.93	8.33	6.36	40.38	27.56
Oil Meal—						
Brown Swiss, first	11.94	5.63	6.19	7.91	32.68	35.65
Brown Swiss, second	12.00	5.00	6.37	8.19	31.25	37.19
Holstein, first	11.69	5.64	8.64	7.37	32.00	34.66
Holstein, second	11.34	4.90	8.03	7.17	33.00	35.56
Shorthorn, first	10.37	5.32	7.77	7.54	34.89	34.20
Shorthorn, second	10.50	5.09	7.71	8.24	33.00	35.46
Jersey, first	12.55	5.25	6.62	7.88	33.49	34.21
Jersey, second	9.84	4.65	7.42	9.02	34.19	34.88
Rolled Oats—						
Jersey, second	8.28	4.97	5.99	16.08	16.19	48.49
Ground Oats—						
Holstein, first	15.48	3.86	3.58	12.79	10.54	53.75
Jersey, second	8.90	3.86	3.68	10.58	10.43	62.55
Shorthorn, first	14.44	3.89	4.79	10.12	9.53	57.23
Shorthorn, second	9.13	4.28	3.44	26.82	9.56	46.77
Union Grains—						
Holstein, first	10.84	3.98	7.80	10.61	26.23	40.54
Holstein, second	8.97	4.36	7.08	9.47	25.88	44.24
Brown Swiss, second	8.68	5.23	7.15	9.83	24.00	45.11
Distillers' Grains—						
Jersey, first	8.52	1.75	12.37	12.86	27.19	37.29
Jersey, second	7.93	3.30	5.27	12.79	29.69	41.02
Shorthorn, second	7.51	2.71	10.38	13.28	28.88	37.24
Malt Sprouts—						
Brown Swiss, first	16.02	8.26	.95	12.51	20.29	41.97
Brown Swiss, second	10.45	8.03	2.58	16.26	22.00	40.68
Corn Hearts—						
Holstein, first	10.68	3.73	11.68	14.60	11.45	47.86
Jersey, first	9.59	1.85	8.57	9.59	21.62	48.78
Jersey ,second	9.72	2.12	9.02	9.85	20.50	49.79
Shorthorn, first	10.76	2.01	9.02	9.84	21.41	46.96
Shorthorn, second	10.41	2.23	8.02	9.77	20.31	49.26
Alfalfa Hay—						
Jersey, second	14.82	8.17	1.38	29.15	13.84	32.64
Holstein, second	11.62	7.23	1.25	36.15	10.81	32.94
Shorthorn, second	12.49	8.97	1.62	29.11	13.97	33.84
Corn Silage—						
Jersey, second	76.34	1.40	.72	4.85	1.88	14.81
Shorthorn, second	69.18	2.54	.57	8.39	2.73	16.59

The awards were made solely from a financial standpoint, charging the cows for the feed consumed according to the agreed valuation of forage and grain, and crediting them for production and gain in weight at the rate of 4 cents per pound for increase in live weight, 25 cents per pound for calculated butter, 3 cents per pound for solids not fat, and 30 cents per pound for butter fat.

Two publications have been made, giving the results of the contest, one by the American Jersey Cattle Club, and the other by the Hon. W. D. Hoard. These deal with the subject from a purely financial standpoint, based upon the money valuation placed upon the different kinds of feed used.

Since the money or market value of feed stuffs is constantly changing, because of variation in supply and demand, and since there are differences of opinion as to feed values, it was thought that by reducing all the feed stuffs consumed by each cow to dry matter and digestible nutrients and calculating the amount of nutriment consumed to a unit of product returned, data would be obtained which would be a valuable contribution to our feeding literature, and which could be used in making comparison in future feeding experiments and public competitive tests. The cost of producing a unit of product at the St. Louis Cow Demonstration may have little or no significance for making comparison with tests made five or ten years later, but by reducing the results to a basis of nutriment we have a definite and unvarying standard for comparison.

The Executive Committee of the American Jersey Cattle Club, composed of Messrs. J. J. Richardson, George E. Peer and W. Gettys, made a full report of all food stuffs consumed and dairy products yielded by each cow in the demonstration; and it is through the courtesy of the Club that the data for this bulletin is available. The liberality, public spirit and enterprise manifested by the American Jersey Cattle Club in this competitive test merits the highest commendation, and shows in a practical way that it has confidence in the ability of the Jersey to demonstrate before the highest kind of an official tribunal her capacity as a large and economical producer of dairy products.

The following table gives the coefficients employed in calculating the digestible nutrients in the various feed stuffs:

TABLE XXI. Digestion Coefficients.

	Protein	Fiber	Nitrogen Free Extract	Ether Extract
Wheat Bran	78.	29.	69.	68.
Hominy Feed	86.	78.	89.	84.
Gluten Feed	86.	78.	89.	84.
Cotton Seed Meal	88.	56.	62.	93.
Oil Meal	89.	57.	78.	89.
Union Grains	73.	97.	80.	95.
Malt Sprouts	80.	33.	68.	100.
Corn Meal	68.		95.	92.
Ground Oats	78.	20.	76.	83.
Corn Hearts	86.	78.	89.	84.
Distillers' Grains	73.	97.	76.	95.
Rolled Oats	78.	20.	76.	83.
Alfalfa Hay	72.	46.	69.	51.
Corn Silage	51.	66.	67.	79.
Green Corn Fodder	59.	59.	74.	74.
" Oats and Peas	76.	60.	68.	68.
" Cow Peas	75.6	59.6	80.6	59.

No analyses were made of the green forage fed, but all available data was used in an effort to secure a fair average composition of the various green feeds during the different stages of the feeding period.

To give the amount of each kind of feed consumed by each cow would require too much space, but to give a general idea of the rations fed to each group the following tables are submitted, showing the amount of each kind of

TABLE XXII.—Feed Consumed by the Swiss and Holstein Cows.

FEED	5 SWISS COWS			15 HOLSTEINS		
	During 120 Days	Per Cow	Per Cow per Day	During 120 Days	Per Cow	Per Cow per Day
Alfalfa Hay	2091.8	418.36	3.49	19818.4	1327.63	11.06
Clover Hay	2001.9	400.38	3.34	96.0		
Green Clover	3298.0	659.60	5.50	10255.0	683.66	5.70
Green Corn	21821.0	4364.20	36.37	59203.0	3946.86	32.89
Green Oats and Peas	4989.4	997.88	8.31	17725.0	1181.66	9.85
Green Cow Peas				17069.0	1137.93	9.48
Malt Sprouts	2120.4	424.08	3.53			
Corn Meal				789.2	52.61	.44
Bran	525.0	105.00	.87	1811.9	120.79	1.00
Hominy Feed	4544.0	908.80	7.57	3207.7	213.84	1.78
Oil Meal	275.6	55.12	.46	541.0	36.06	.30
Cottonseed Meal	518.5	103.70	.86	695.5	46.36	.39
Ground Oats				99.5	6.63	.05
Gluten Feed	2416.3	483.26	4.03	966.3	64.42	.54
Union Grains	3561.7	712.34	5.94	22384.3	1492.29	12.43
Wheat Middlings				134.5	8.96	.07
Corn Hearts				4483.1	298.87	2.49

feed consumed by each group during the 120 days, the average amount given per cow during the 120 days, and the average amount per day. The cows in each group were not fed exactly the same kind of a ration, neither were all the feed stuffs fed the entire period, but the average given in the tables is the amount that would have been received if fed to each cow in the group during the entire period:

TABLE XXIII.—Feed Consumed by the Jersey and Shorthorn Cows.

FEED	25 JERSEYS			25 SHORTHORNS		
	During 120 Days	Per Cow	Per Cow per Day	During 120 Days	Per Cow	Per Cow per Day
Alfalfa Hay	63174.0	2527.00	21.06	29312.0	1172.48	9.77
Clover Hay	1274.0	50.96	.42	5602.0	224.08	1.87
Corn Silage	36782.5	1471.30	12.26	45297.0	1811.88	15.10
Corn Meal	9454.7	378.19	3.15	787.0	31.48	.26
Bran	7851.5	314.06	2.62	10271.5	410.86	3.42
Hominy Feed	1928.5	77.14	.64	6689.0	267.56	2.23
Oil Meal	5384.0	215.36	1.79	4190.0	167.60	1.40
Cottonseed Meal	1706.0	68.24	.57	4073.0	162.92	1.36
Ground Oats	3120.0	124.80	1.04	7303.0	292.12	2.43
Gluten Feed	12491.8	499.67	4.16	8618.0	344.72	2.87
Distillers' Grains	2688.7	107.55	.90	5462.0	218.48	1.82
Corn Hearts	4167.0	166.68	1.39	6164.0	246.56	2.05

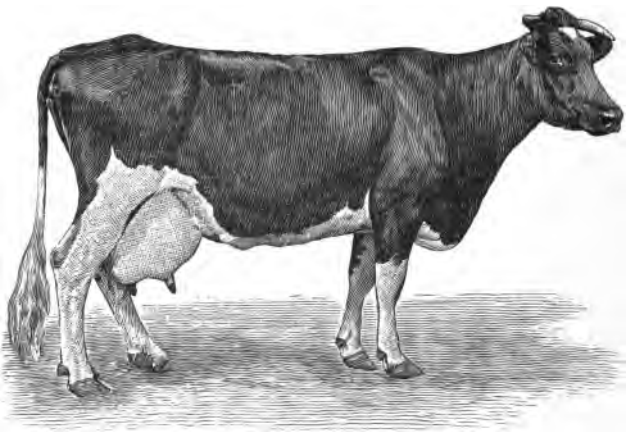
It will be seen by these tables that the cows consumed an enormous amount of feed, nearly twice the amount given in ordinary feeding; that the Swiss and Holstein cows received a large amount of green forage; that the Jerseys consumed a large quantity of Alfalfa hay; and that the Shorthorns received considerably lighter rations than did the other groups.

TABLE XXIV.—Daily Average of Dry Matter and Nutrients Consumed, and Dairy Products Yielded by Each Cow.

Official No. of Cow	Dry Matter	DIGESTIBLE			Milk	Per cent Fat	Butter Fat	Solids Not Fat
		Protein	Carbohydrates	Fat				
Swiss								
1	39.02	4.960	20.620	1.645	51.05	3.43	1.75	4.363
2	33.79	4.310	17.490	1.460	36.69	3.90	1.43	3.225
3	37.85	4.825	19.985	1.565	38.49	3.84	1.48	3.585
4	39.91	5.130	22.055	1.675	45.29	3.64	1.65	4.010
5	41.27	5.330	21.955	1.745	49.37	3.40	1.68	4.410
Holsteins								
6	39.80	4.855	20.025	1.700	51.45	3.46	1.78	3.96
7	41.15	5.185	20.475	1.760	47.16	3.20	1.51	3.61
8	40.68	5.155	20.355	1.820	55.25	3.35	1.85	4.54
9	38.30	4.875	19.205	1.725	50.33	3.12	1.57	3.84
10	40.64	4.955	19.775	1.785	51.97	3.17	1.65	4.39

TABLE XXIV.—Daily Average of Dry Matter and Nutrients Consumed, and Dairy Products Yielded by Each Cow —(Continued.)

Official No. of Cow	Dry Matter	DIGESTIBLE			Milk	Per cent Fat	Butter Fat	Solids Not Fat
		Protein	Carbohydrates	Fat				
11	40.79	5.030	20.300	1.745	54.36	3.31	1.80	4.59
12	39.66	5.130	19.805	1.735	53.38	3.82	2.04	4.19
13	41.17	5.265	20.575	1.805	57.74	3.67	2.12	4.41
14	39.08	4.995	19.800	1.695	52.60	3.14	1.65	3.98
15	41.91	4.355	20.870	1.815	56.60	3.53	2.00	4.72
16	39.01	4.995	19.220	1.675	47.26	3.51	1.67	3.68
17	40.40	5.175	20.155	1.760	55.06	3.36	1.85	4.29
18	40.33	5.160	20.150	1.750	51.94	3.64	1.89	4.23
19	39.21	4.855	19.845	1.740	48.78	3.57	1.74	3.98
20	40.97	5.395	20.535	1.885	67.51	3.48	2 35	5.17
Jerseys								
21	37.41	5.137	18.456	.915	42.84	4.87	2.088	3.720
22	36.23	4.961	17.737	.863	45.31	4.31	1.952	3.905
23	36.95	5.154	17.888	.894	40.88	4.82	1.972	3.574
24	33.46	4.610	16.187	.900	42.34	3.85	1.632	3.583
25	36.50	4.819	17.858	.844	46.29	4.60	2.128	3.901
26	37.17	4.915	18.321	.943	47.71	4.44	2.121	4.181
27	31.96	4.324	16.195	.816	33.79	4.94	1.672	2.929
28	34.36	4.721	16.830	.836	34.23	5.06	1.735	2.998
29	33.80	4.571	16.623	.811	37.47	4.77	1.791	3.256
30	36.32	5.072	17.529	.899	42.67	4.81	2.054	3.677
31	34.61	4.830	16.975	.877	41.23	4.82	1.988	3.637
32	33.87	4.793	16.530	.814	42.02	4.17	1.754	3.751
33	33.23	4.655	16.030	.785	35.95	5.05	1.815	3.141
34	33.73	4.709	16.537	.877	41.03	4.23	1.737	3.546
35	35.03	4.913	16.986	.889	41.62	4.81	2.002	3.703
36	35.85	4.921	17.342	.901	38.78	4.16	1.615	3.442
37	39.51	5.228	19.359	.923	48.36	4.80	2.335	4.357
38	35.68	4.875	18.306	.855	42.39	4.84	2.054	3.821
39	37.69	5.012	18.710	.906	43.44	5.08	2.207	3.806
40	35.99	4.935	17.470	.905	40.97	5.06	2.073	3.638
41	36.56	4.909	18.041	.908	42.30	4.02	1.702	3.574
42	32.64	4.442	15.743	.807	39.27	4.62	1.818	3.452
43	36.59	5.158	17.874	.890	42.46	4.77	2.028	3.781
44	38.37	5.459	18.811	.983	39.00	5.00	1.952	3.481
45	36.99	5.163	18.073	1.001	45.33	4.84	2.196	3.980
Shorthorns								
46	33.18	4.820	15.954	1.278	37.57	3.67	1.38	3.23
47	32.173	4.508	15.125	1.109	34.49	3.83	1.32	2.97
49	35.01	5.120	16.514	1.294	34.70	3.97	1.38	3.01
50	34.50	4.872	16.402	1.252	34.10	3.50	1.19	2.99
51	37.37	5.494	17.582	1.400	41.86	3.89	1.63	3.56
52	31.37	4.566	15.048	1.257	33.80	4.26	1.44	2.94
53	28.09	3.803	12.181	1.049	29.70	3.60	1.07	2.50
54	28.51	3.916	13.884	1.082	38.20	3.16	1.20	3.25
56	29.47	4.203	14.467	1.083	38.23	3.37	1.29	3.25
57	32.97	4.485	16.043	1.202	34.03	3.70	1.26	2.97
58	29.06	4.315	14.587	1.193	34.61	3.67	1.27	2.98
59	30.11	4.359	14.553	1.187	31.64	3.81	1.21	2.81
60	28.39	3.339	14.034	1.153	35.30	3.68	1.30	3.10
61	28.92	4.303	13.997	1.176	25.59	3.63	.93	2.21
63	31.40	4.566	15.216	1.273	43.39	4.01	1.74	3.72
64	31.21	4.305	14.818	1.080	28.97	4.00	1.16	2.52
65	29.09	4.392	13.602	.975	37.07	3.72	1.38	3.24
66	28.43	3.892	13.491	.952	39.72	3.78	1.50	3.42
68	28.78	4.020	13.779	1.003	41.24	3.35	1.38	3.40
69	31.80	4.418	15.180	1.099	34.66	3.63	1.26	3.01
70	27.31	3.586	11.901	.874	30.10	3.29	.99	2.50
71	32.66	4.799	15.353	1.194	36.80	3.21	1.18	3.18
72	28.18	3.959	13.748	1.106	32.49	4.06	1.32	2.85
73	31.26	4.414	14.899	1.084	33.77	3.82	1.29	2.88
74	30.01	4.103	14.291	1.004	37.63	3.59	1.35	3.25



Holstein cow, Shadybrook Gerben, producing the largest yield of milk, butter fat and total solids.

The foregoing table shows that the Holstein cow No. 20, being Shadybrook Gerben, produced the largest yield in milk, butter fat and solids not fat. Her daily average yield was, of milk 67.51 lbs., of butter fat 2.35 lbs., and of solids not fat 5.17 lbs., making a total daily yield of 7.52 lbs. of milk solids. Second in rank, based upon the sum of the milk solids, is the Holstein cow No. 15, Heeringer's Pauline 2nd, producing 2.00 lbs. of butter fat and 4.72 lbs. of solids not fat, making a daily yield of 6.72 lbs. total milk solids. Upon a similar basis, the Jersey cow No. 37, Loretta D., ranks third, giving 2.335 lbs. of butter fat, and 4.357 lbs. of solids not fat, making a daily average yield of 6.692 lbs. of water-free milk solids. In considering this dairy demonstration from its nutritive phase, the sum of the milk solids yielded is not a good basis upon which to measure the performance of a cow. Butter fat has 2.2 times the energy value, and, within certain limits, the nutritive value, of solids not fat. By reducing, therefore, the butter fat to an equivalent of solids not fat, and adding this to the solids not fat, it gives a fair expression of a cow's performance. Upon this basis, the record of performance and rank stands as follows:

DAILY YIELD OF MILK SOLIDS.

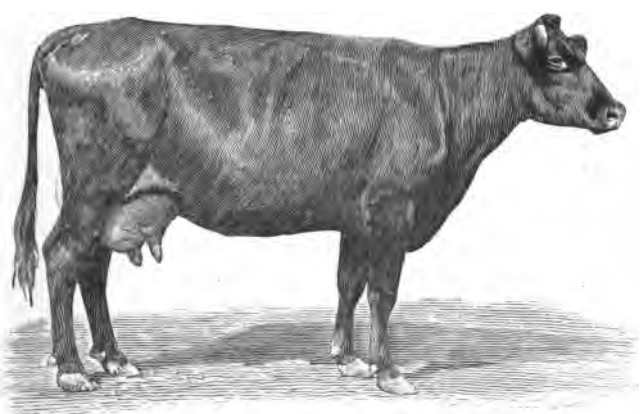
1. Shadybrook Gerben, Holstein—

	lbs.
Butter Fat, 2.35x2.2=	5.17
Solids not fat	5.17
Total	10.34

2. Loretta D., Jersey—
   Butter Fat, 2.335x2.2=.....5.137
   Solids not fat 4.357
   Total.....9.494
3. Heeringer's Pauline 2nd, Holstein—
   Butter Fat, 2.x2.2= 4.40
   Solids not fat 4.72
   Total.....9.12

The remarkable productive power of these cows is shown by the fact that the milk solids produced by the three during the 120 days are equivalent to the food value of five fat steers weighing 1126 lbs. each. Making similar calculations on the total production of the 70 cows in the test during the 120 days, it is found that they produced milk solids equivalent to the food value of 70 fat steers weighing 1405 lbs. each.

Among the Shorthorns, No. 63, 16th Belle of Trowbridge, ranks first, with 1.74 lbs. of butter fat, 3.72 lbs. of solids not fat, making 5.46 lbs. of total solids, or 7.548 lbs. of solids equivalent to solids not fat.



16th Belle of Trowbridge, the type of shorthorn that is a large and economical producer.

Of the Swiss cows, No. 1, Nellie H., produced the largest yield, giving daily 1.75 lbs, of butter fat, and 4 36 lbs. of solids not fat, making 6.11 lbs. "total solids," or 8.21 lbs. of solids equivalent to solids not fat.

TABLE XXV.—Daily Average of Dry Matter and Nutrients Consumed, and Dairy Products Yielded by Each Group.

BREED	Dry Matter	Protein	Carbohydrates	Fat	Milk	% Fat	Butter Fat	Solids Not Fat
Swiss	38.37	4.912	20.422	1.619	44.18	3.62	1.60	3.92
Holsteins	40.21	5.092	20.073	1.760	53.43	3.42	1.83	4.24
Jerseys	35.62	4.891	17.457	.882	41.51	4.67	1.937	3.63
Shorthorns	30.75	4.338	14.658	1.134	35.19	3.68	1.297	3.03

By the foregoing summary, giving the daily average of dry matter and nutrients consumed, it appears that the feed consumed provided dry matter and nutrients considerably in excess of the feeding standard, so far as the first three breeds are concerned, and that the Shorthorns received protein and ether extract, or fat, in excess, and were short in carbohydrates. The average daily yield of milk, butter fat and solids not fat was large, considering the conditions under which the test was made, and must have been gratifying to the friends of each of the breeds; but considering the nutrients consumed, the yield was below the amount that should have been made under normal conditions, except as to the Shorthorns.

The cows received nearly twice as much protein as was needed, and all but the Jerseys received about double the amount of ether extract that seemed necessary; but the excess in this nutrient did no harm, which is more than can be said for the excess of protein fed, which is a fruitful source of barrenness, shy breeding, rheumatism, gout and other disorders. Excess of carbonaceous nutrients may temporarily produce barrenness and shy breeding, but when thus produced, it is easily remedied by bringing the cows to physical spareness, but this is not the case when it is caused by excess of protein. Heavy feeding of highly nitrogenous feeds has injured many, and it may be safe to say, most of our great cows and their progeny. An abnormal stimulation and development of the digestive and mammary organs brings to them an abnormal flow of blood, and the organs of reproduction suffer proportionally, and barrenness, shy breeding or weak progeny often follows. Because of the injurious effects of heavy feeding of highly nitrogenous concentrates, purchasers of cows with large records have, as a rule, been grievously disappointed in both the cows and their subsequent off-

spring. To so feed that a cow will gradually increase her yield from year to year until she reaches the meridian of life, tends toward the improvement of her progeny—is constructive. To force a cow beyond her normal limit of performance is destructive.

When the daily nutriment supply just meets the needs of an animal for the maintenance of the body and for the products daily yielded or produced, be it either in the form of milk solids, gain in weight, or energy expended in labor, the amount of net nutriment required for the production of a unit of a given product is remarkably uniform. If the daily supply is above its needs, the excess is not always utilized; especially is this the case in milk production; but if the excess continues for some considerable time, a portion of it may be stored in the body, producing a gain in weight. By deducting from the daily average nutrients supplied each breed per cow, the nutrients actually required daily for maintenance, for milk solids yielded, and for the daily gain in body weight, the remainder is approximately the excess of nutriment supplied above their needs.

The Feeding standard employed in calculating the daily average nutrients required for the production of the daily average yield of milk by each breed, is based upon the results obtained in feeding experiments in milk production at the Minnesota Experiment Station, covering a period of twelve years, and prescribes the net nutrients required for the production of a pound of milk ranging from 2.5 per cent butter fat to 7 per cent. The standard for the food of maintenance employed is also based upon results obtained by a series of experiments at this Station with cows, covering four winter's work, where it was found that .63 of a pound of protein, 5.75 pounds of carbohydrates, and .12 of a pound of ether extract daily per 1000 lbs. live weight, provided ample nourishment and a daily average gain of .23 of a pound. On account of the gain in live weight, and to put it in more simple form, the coefficients used in the statement following were .07 of a pound of protein, .5 of a pound of carbohydrates and .01 of a pound of ether extract per 100 lbs. live weight.

The net nutriment chargeable to a pound of gain in live weight was obtained several years ago in the Dairy

Division with seven steers, covering a period of 365 consecutive days of exclusive stall feeding, and resulted in a pound of gain to 3.2 lbs. of net nutriment.

The following statement shows the daily average of nutrients consumed and the apparent disposition made of them:

Swiss cows, weighing 1329 lbs., yielding daily 44.18 lbs. Milk, testing 3.62 per cent Butter Fat, and gaining daily .67 of a lb. in live weight.

	Protein	C. H.	Fat	
Daily average nutrients in ration fed	4.912	20.422	1.619	
Nutrients required for milk yielded	2.015	9.503	.672	
Remaining for maintenance and gain	2.897	10.919	.947	
Nutrients for maintenance	.930	6.645	.133	
Nutrients in excess	1.967	4.274	.814	
Amounting in starch equivalent to				8.033 lbs.
Amount chargeable to .67 of a lb. gain in weight				2.144 "
Daily loss or waste in nutriment per cow				5.889 "

Holstein Cows, weighing 1289 lbs., yielding 53.43 lbs. of Milk daily, testing 3.42 per cent Butter Fat, and gaining daily .82 of a lb. in live weight.

	Protein	C. H.	Fat	
Daily average nutrients in ration fed	5.092	20.073	1.760	
Nutrients required for milk production	2.372	11.006	.780	
Remaining for maintenance and gain	2.720	9.067	.980	
Nutrients for maintenance	.902	6.445	.129	
Nutrients in excess	1.818	2.622	.851	
Amounting in starch equivalent to				6.312 lbs.
Amount chargeable to .82 lbs. of gain in weight				2.624 "
Daily loss or waste in nutriment per cow				3.688 "

Jersey Cows, weighing 948 lbs., yielding 41.51 lbs. of Milk daily, testing 4.7 per cent Fat, and gaining daily .6 of a lb. in live weight.

	Protein	C. H.	Fat	
Daily average nutrients in ration fed	4.891	17.457	.882	
Nutrients required for milk production	2.166	10.790	.763	
Remaining for maintenance and gain	2.725	6.667	.119	
Nutrients for maintenance	.664	4.740	.095	
Nutrients in excess	2.061	1.927	.024	
Amounting in starch equivalent to				4.041 lbs.
Amount chargeable to .6 of a lb. gain in weight				1.920 "
Daily loss or waste in nutriment per cow				2.121 "

Shorthorn Cows, weighing 1257 lbs., yielding 35.19 lbs. of Milk daily, testing 3.7 per cent Fat, and gaining daily .86 of a lb. in live weight.

	Protein	C. H.	Fat	
Daily average nutrients in ration fed	4.338	14.658	1.134	
Nutrients required for milk production	1.626	7.744	.546	
Remaining for maintenance and gain	2.712	6.914	.588	
Nutrients for maintenance	.880	6.285	.126	
Nutrients in excess	1.832	.629	.462	
Amounting in starch equivalent to				3.477 lbs.
Amount chargeable to .86 of a lb. gain in weight				2.752 "
Daily loss or waste in nutriment per cow				.725 "

From the foregoing statements it appears that the Swiss cows received on an average daily 5.889 lbs. more nutriment than was assimilated; that the daily average excess of nutriment received by the Holsteins, per cow, was 3.688 lbs.; for the Jerseys 2.121 lbs., and for the Shorthorns .725 of a lb.

The following table gives the breed, the number and name of each cow, average weight, average pounds of nutriment consumed daily, and nutriment required for the production of 100 lbs. of milk, 1 lb. of butter fat, and 1 lb. of total solids. The numbers in the column headed "Nutriment Daily" are simply the sum of the nutrients consumed daily, and the "Total Solids" are the solids not fat plus the butter fat multiplied by 2.2.

TABLE XXVI.— Names of Cows, Average Pounds of Nutriment Consumed Daily, and Nutriment to Dairy Products Yielded.

	No. and Name of Cow	Average Weight of Cow	Nutriment Daily	Nutriment to		
				100 lbs. of Milk	1 lb. Butter Fat	1 lb. Total Solids
	Swiss					
1	Nellie H.	1248	27.227	53.333	15.557	3.315
2	Folie,	1181	23.274	63.886	16.392	3.658
3	Maud H.	1384	26.375	68.524	17.847	3.858
4	Laura D.	1367	28.860	63.723	17.518	3.780
5	Florine,	1467	29.030	58.801	17.280	3.581
	Holsteins'					
6	Jolie 4th's Pauline D. K.	1398	26.580	51.662	14.932	3.374
7	Dorinda De Kol 2nd	1438	27.420	58.142	18.159	3.955
8	Jolie Johanna,	1263	27.330	49.466	14.773	3.174
9	Daisy Lamb P. D. K.	1225	25.805	51.262	16.433	3.537
10	Joe Bach Josephine,	1343	26.515	51.010	16.067	3.305
11	Bessie Wayne's C.	1327	27.075	49.807	15.042	3.166
12	Anchaletta D. K.	1283	26.670	49.962	13.073	3.073
13	Maple Croft's D. K.	1342	27.645	47.878	13.040	3.047
14	Lady Truth Gerben	1286	26.490	50.361	16.054	3.480
15	Heeringer's Pauline 2nd	1223	28.040	49.541	13.520	3.074
16	De Kol's De Jung	1191	25.890	54.784	15.503	3.525
17	Mary of Glencoe	1251	27.085	49.201	14.643	3.240
18	Hadria 2nd	1236	27.060	52.098	14.317	3.226
19	Sally Clotilde	1239	26.440	54.202	15.195	3.386
20	Shadybrook Gerben	1293	27.805	41.186	11.832	2.689
	Jerseys					
21	Oonan 11th of H. F.	975	24.511	57.21	11.74	2.948
22	Airy's Vinie Hugo	989	23.561	52.00	12.07	2.873
23	Blossom of Florence	1047	23.937	58.55	12.14	3.025
24	Chroma 3rd of H. F.	935	21.697	51.24	13.30	3.025
25	Dorinda Darling	902	23.521	50.81	11.05	2.740
26	Prize May's Duchess	1049	24.180	50.68	11.40	2.733
27	Yoethe Koffee of L.	927	21.335	63.14	12.76	3.229
28	Bloomfield Oonan	927	22.387	65.40	12.90	3.285
29	Clarion Girl	781	22.006	58.73	12.29	3.058
30	Ella Golden	984	23.501	55.08	11.44	2.867
31	Aaron's Queen	973	22.686	55.02	11.41	2.832
32	Dela S. of Eau Claire	848	22.137	52.68	12.62	2.909
33	Lassie Easter Pogis	929	21.470	59.72	11.83	3.009
34	Rosa's Glory	868	22.123	53.92	12.73	3.003
35	Annie of Seekonk	960	22.789	54.75	11.38	2.810
36	Zaza of Menlo	1046	23.165	59.73	14.34	3.311

TABLE XXVI.—Names of Cows, Average Pounds of Nutriment Consumed Daily, and Nutriment to Dairy Products Yielded.—(Continued.)

	No. and Name of Cow	Average Weight of Cow	Nutriment Daily	Nutriment to 100 lbs. of Milk	Nutriment to 1 lbs. Butter Fat	Nutriment to 1 lb. Total Solids
37	Loretta D.	1036	25.510	52.75	10.93	2.687
38	Oonan 23rd of H. F.	914	24.039	56.71	11.22	2.882
39	Diploma's B. Lassie	1036	24.627	56.69	11.16	2.843
40	Baronette of Ingleside	883	23.311	56.90	11.24	2.843
41	Gorgeous Rosebud	914	23.859	56.40	14.02	3.260
42	Hoodoo Jane	787	20.993	53.46	11.55	2.817
43	Diploma's B .Bessie	1001	23.923	56.34	11.79	2.902
44	King's Gazelle Fawn	1090	25.253	64.75	12.94	3.248
45	Eurybia	899	24.237	53.47	11.03	2.750
	Shorthorns					
46	Mary	1405	22.052	58.69	15.98	3.519
47	Fillpail 2nd of S. P.	1196	20.742	60.25	15.74	3.538
49	Mary Ann	1380	22.928	66.07	16.62	3.659
50	Kitty Clay 10th	1297	22.526	66.06	18.92	4.016
51	Era S. 10th	1397	24.476	58.47	15.01	3.427
52	Rowena 2nd	1442	20.871	61.75	14.49	3.417
53	Janesville C. Rose 102	1286	17.033	57.35	15.92	3.509
54	Janesville C. Rose 125	1013	18.882	49.43	15.73	3.206
56	Young Mary 33rd	1172	19.753	51.67	15.31	3.244
57	44th Profitable	1226	21.730	63.85	17.24	3.784
58	Lady Steele	1306	20.095	58.06	15.82	3.480
59	Belle of York	1408	20.099	63.52	16.61	3.490
60	Daisy Dean	1289	18.526	52.48	14.25	3.108
61	Bright Eyes of S. L.	1214	19.476	76.11	20.94	4.576
63	16th Belle of T.	1099	21.055	48.52	12.10	2.789
64	Lygia	1385	20.203	69.73	17.41	3.983
65	Eleanor Lee 2nd	1325	18.969	51.17	13.74	3.022
66	Pale Face	1094	18.335	46.16	12.22	2.728
68	Lady Clara 13th	1184	18.802	45.59	13.62	2.885
69	Lady Clara 4th	1230	20.697	59.71	16.42	3.579
70	Iris 2nd	1223	16.361	54.35	16.52	3.497
71	Kitty Clay 20th	1146	21.346	58.00	18.09	3.695
72	Viola	1206	18.813	57.90	14.25	3.269
73	Kitty Clover 3rd	1314	20.397	60.40	15.81	3.567
74	Red Bird	1135	19.398	51.56	14.37	3.118

TABLE XXVII.—Summary of Results by Breeds.

BREED	Average Weight of Cows	Nutriment Daily	Lbs. of Nutriment to 100 lbs. of Milk	Lbs. of Nutriment to 1 lb. Butter Fat	Lbs. of Nutriment to 1 lb. Total Solids
Swiss	1329	26.953	61.653	16.919	3.635
Holsteins	1289	26.924	50.705	14.839	3.283
Jerseys	948	23.230	56.245	12.051	2.955
Shorthorns	1257	20.130	57.204	15.520	3.421

From this table it will be seen that there was a marked difference in the amount of nutriment required by the different breeds for the production of a pound of butter fat; the Jersey cows returning a pound of butter fat to 12.051 pounds of nutriment, the Holsteins requiring 14.839 lbs., the Shorthorns 15.520 lbs., and the Swiss cows 16.919 lbs. For the production of a pound of milk solids, in which the butter fat was reduced to an equivalent of solids not fat, the Jerseys required 2.955 lbs. of nutriment to one lb.

of milk solids, the Holsteins 3.283 lbs., the Shorthorns 3,421 lbs., and the Swiss cows 3.638 lbs. The breed that comes nearest to the true dairy type produces dairy products with the smallest amount of nutriment, and the farther they deviate from this type, the more nutriment is required for the production of a unit of dairy product.

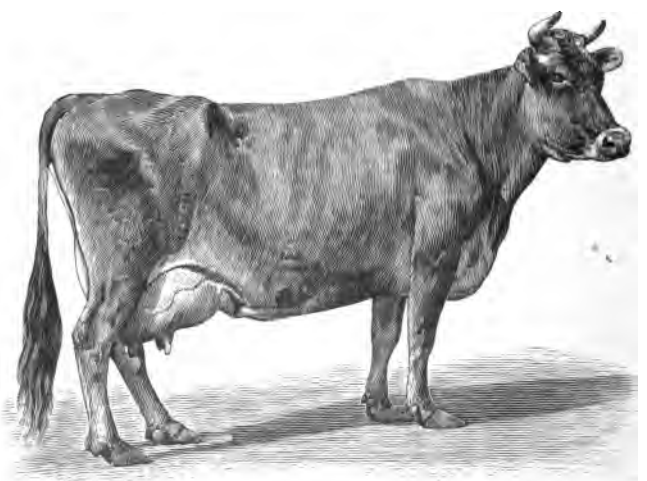
The following table gives the rank of each cow participating in the test, the name, breed, average live weight, nutriment consumed daily, and nutriment required for the production of a pound of butter fat:

TABLE XXVIII-Rank of Cows, Based upon Nutriment Required for the Production of a Pound of Butter Fat.

Rank	NAME OF COW	BREED	Average Live Weight	Nutriment Daily	Nutriment to 1 lb. Butter Fat
1st	Loretta D	Jersey	1036	25.510	10.93
2nd	Eurybia	"	899	24.237	11.03
3rd	Dorinda Darling	"	902	23.521	11.05
4th	Diploma's Brown Lassie	"	1036	24.627	11.16
5th	Oonan 23rd of Hood Farm	"	914	24.039	11.22
6th	Baronette of Ingleside	"	883	23.311	11.24
7th	Annie of Seekonk	"	960	22.789	11.38
8th	Prize May's Pogis	"	1049	24.180	11.40
9th	Aaron's Queen	"	973	22.686	11.41
10th	Ella Golden	"	984	23.501	11.44
11th	Hoodoo Jane	"	787	20.993	11.55
12th	Oonan 11th of Hood Farm	"	976	24.511	11.74
13th	Diploma's Brown Bessie	"	1001	23.923	11.79
14th	Lassie Easter Pogis	"	929	21.470	11.83
15th	Shadybrook Gerben	Holstein	1293	27.805	11.83
16th	Airy's Vinie Hugo	Jersey	989	23.561	12.07
17th	16th Belle of Trowbridge	Shorthorn	1099	21.055	12.10
18th	Blosson of Florence	Jersey	1047	23.937	12.14
19th	Pale Face	Shorthorn	1094	18.335	12.22
20th	Clarion Girl	Jersey	781	22.006	12.29
21st	Dela S. of Eau Claire	"	848	22.137	12.62
22nd	Rosa's Glory	"	868	22.123	12.73
23rd	Yoethe Koffee of Lawn	"	927	21.335	12.76
24th	Bloomfield Oonan	"	927	22.387	12.90
25th	King's Gazelle Fawn	"	1090	25.253	12.94
26th	Maple Croft's De Kol	Holstein	1342	27.645	13.04
27th	Anchalette De Kol	"	1283	26.670	13.07
28th	Chroma 3rd of Hood Farm	Jersey	935	21.697	13.30
29th	Heeringer's Pauline 2nd	Holstein	1223	28.040	13.52
30th	Lady Clara 13th	Shorthorn	1184	18.802	13.62
31st	Eleanor Lee 2nd	"	1325	18.969	13.74
32nd	Gorgeous Rosebud	Jersey	914	23.859	14.02
33rd	Viola	Shorthorn	1206	18.813	14.25
34th	Daisy Dean	"	1289	18.526	14.25
35th	Hadria 2nd	Holstein	1236	27.060	14.32
36th	Zaza of Menlo	Jersey	1046	23.165	14.34
37th	Red Bird	Shorthorn	1185	19.398	14.37
38th	Rowena 2nd	"	1442	20.871	14.49
39th	Mary of Glencoe	Holstein	1251	27.085	14.64
40th	Jolie Johanna	"	1263	27.330	14.77
41st	Jolie 4th's Pauline D. K.	"	1398	26.580	14.93
42nd	Era S. 10th	Shorthorn	1397	24.476	15.01
43rd	Bessie Wayne's Champion	Holstein	1327	27.075	15.04
44th	Sally Clotilde	"	1239	26.440	15.19
45th	Young Mary 33rd	Shorthorn	1172	19.753	15.31
46th	De Kol De Jung	Holstein	1191	25.890	15.50
47th	Nellie H.	Swiss	1248	27.227	15.56

TABLE XXVIII.—Rank of Cows, Based upon Nutriment Required for the Production of a Pound of Butter Fat.—(Continued.)

Rank	NAME OF COW	BREED	Average Live Weight	Nutriment Daily	Nutriment to 1 lb. Butter Fat
48th	Janesville C. Rose 125	Shorthorn	1013	18.882	15.73
49th	Fillpail 2nd of S. P.	"	1196	20.742	15.74
50th	Kitty Clover 3rd	"	1314	20.397	15.81
51st	Lady Steele	"	1306	20.095	15.82
52nd	Janesville C. Rose 102	"	1286	17.033	15.92
53rd	Mary	"	1405	22.052	15.98
54th	Lady Truth Gerben	Holstein	1286	26.490	16.05
55th	Joe Bach Josephine	"	1343	26.515	16.07
56th	Folie	Swiss	1181	23.274	16.39
57th	Lady Clara 4th	Shorthorn	1230	20.697	16.42
58th	Daisy Lamb	Holstein	1225	25.805	16.43
59th	Iris 2nd	Shorthorn	1223	16.361	16.52
60th	Belle of York	"	1408	20.099	16.61
61st	Mary Ann	"	1380	22.928	16.62
62nd	44th Profitable of Oakland	"	1226	21.730	17.24
63rd	Florine	Swiss	1467	29.030	17.28
64th	Lygia	Shorthorn	1385	20.203	17.41
65th	Laura D	Swiss	1367	28.860	17.52
66th	Maud H	"	1384	26.375	17.85
67th	Kitty Clay 20th	Shorthorn	1146	21.346	18.09
68th	Dorinda De Kol	Holstein	1438	27.420	18.16
69th	Kitty Clay 10th	Shorthorn	1297	22.526	18.92
70th	Bright Eyes of S. L.	"	1214	19.476	20.94



Jersey cow, Loretta D., ranking 1st in economy of production.

From the foregoing table it is seen that the Jersey cow Loretta D. returned a pound of butter fat to 10.93 lbs. of nutriment, being the smallest amount required by any cow in the test, and she is followed by thirteen other Jerseys. The highest rank attained by a Holstein was No. 15, Shadybrook Gerben. She is followed closely by the Shorthorn 16th Belle of Trowbridge, ranking as 17th,

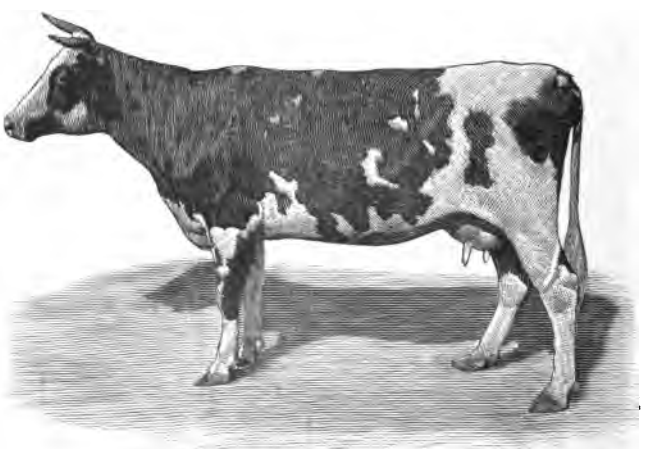
and Pale Face ranking 19th. The fact that only one Jersey appears in the last half of the list shows that the breed stands first on the score of economy of production. All of the cows taking high rank as to nutriment required for the production of a pound of butter fat are of the superlative dairy type. Shadybrook Gerben, Pale Face and 16th Belle of Trowbridge were especially noted for spareness, considering the breeds to which they belonged. All of the cows that required relatively a large amount of nutriment to a pound of butter fat were of the more blocky type. The results of this competitive test show that type is the most important point in determining the adapability of a cow to economical dairy work. Shadybrook Gerben outranked by far the other Holsteins because she had a conformation better suited to dairy work. The cases of Pale Face and 16th Belle of Trowbridge, among the Shorthorns, were the same.

TABLE XXIX.- Rank of Cows, Based upon Nutriment Required for the Production of a Pound of Milk Solids.

Rank	NAME OF COW	BREED	Nutriment to 1 lb. Milk Solids
1st	Loretta D	Jersey	2.687
2nd	Shadybrook Gerben	Holstein	2.689
3rd	Pale Face	Shorthorn	2.728
4th	Prize May's Duchess	Jersey	2.733
5th	Dorinda Darling	"	2.740
6th	Eurybia	"	2.750
7th	16th Belle of Trowbridge	Shorthorn	2.789
8th	Annie of Seekonk	Jersey	2.810
9th	Hoodoo Jane	"	2.817
10th	Aarons' Queen	"	2.832
11th	Diploma's Brown Lassie	"	2.843
12th	Baronette of Ingleside	"	2.843
13th	Ella Golden	"	2.867
14th	Airy's Vinie Hugo	"	2.873
15th	Oonan 23rd of Hood Farm	"	2.882
16th	Lady Clara 13th	Shorthorn	2.885
17th	Diploma's Brown Bessie	Jersey	2.902
18th	Dela S. of Eau Clair	"	2.909
19th	Oonan 11th of Hood Farm	"	2.948
20th	Rosa's Glory	"	3.003
21st	Lassie Easter Pogis	"	3.009
22nd	Eleanor Lee 2nd	Shorthorn	3.022
23rd	Chroma 3rd of Hood Farm	Jersey	3.025
24th	Blossom of Florence	"	3.025
25th	Maple Croft's De Kol	Holstein	3.047
26th	Clarion Girl	Jersey	3.058
27th	Anchalette De Kol	Holstein	3.073
28th	Heeringer's Pauline 2nd	"	3.074
29th	Daisy Dean	Shorthorn	3.108
30th	Red Bird	"	3.118
31st	Bessie Wayne's Champion	Holstein	3.166
32nd	Jolie Johanna	"	3.174
33rd	Janesville C. Rose 125	Shorthorn	3.206
34th	Hadria 3rd	Holstein	3.226
35th	Yoethe Koffee of Lawn	Jersey	3.229

TABLE XXIX.—Rank of Cows, Based upon Nutriment Required for the Production of a Pound of Milk Solids.—(Continued.)

Rank	NAME OF COW	BREED	Nutriment to 1 lb. Milk Solids
36th	Mary of Glencoe	Holstein	3.240
37th	Young Mary 33rd	Shorthorn	3.244
38th	King's Gazelle Fawn	Jersey	3.248
39th	Gorgeous Rosebud	"	3.260
40th	Viola	Shorthorn	3.269
41st	Bloomfield Oonan	Jersey	3.285
42nd	Joe Bach Josephine	Holstein	3.305
43rd	Zaza of Menlo	Jersey	3.311
44th	Nellie H.	Swiss	3.315
45th	Jolie 4th Pauline De Kol	Holstein	3.374
46th	Sally Clothilde	"	3.386
47th	Rowena 2nd	Shorthorn	3.417
48th	Era S. 10th	"	3.427
49th	Lady Truth Gerben	Holstein	3.480
50th	Lady Steele	Shorthorn	3.480
51st	Belle of York	"	3.490
52nd	Iris 2nd	"	3.497
53rd	Janesville C. Rose 102	"	3.509
54th	Mary	"	3.519
55th	De Kol De Jung	Holstein	3.525
56th	Daisy Lamb P. D. K.	"	3.537
57th	Fillpail 2nd of S. P.	Shorthorn	3.538
58th	Kitty Clover 3rd	"	3.567
59th	Lady Clara 4th	"	3.579
60th	Florine	Swiss	3.581
61st	Folie	"	3.658
62nd	Mary Ann	Shorthorn	3.659
63rd	Kitty Clay 20th	"	3.695
64th	Laura D.	Swiss	3.780
65th	44th Profitable	Shorthorn	3.784
66th	Maud H.	Swiss	3.858
67th	Dorinda De Kol	Holstein	3.955
68th	Lygia	Shorthorn	3.983
69th	Kitty Clay 10th	"	4.016
70th	Bright Eyes	"	4.576



Shorthorn cow Pale Face, ranking 3rd in economy of production of milk solids.

In nutriment required for the production of total milk solids, the Jersey cow Loretta D. ranked first, returning

a pound of total milk solids, the butter fat expressed in an equivalent of solids not fat, to 2.687 lbs. of nutriment, while Shadybrook Gerben required 2.689 lbs., and the Shorthorn Pale Face 2.728 lbs. The Holstein, Swiss and Shorthorn breeders should make a note of this, and make strenuous efforts to breed toward a higher dairy type, which clearly makes for larger and more economical production. An animal with a bulky, blocky form may do exceptionally good work for a short time, so far as yield is concerned, but it generally lacks staying qualities. The wonderful performance of the Jerseys in this respect is clearly shown in the following table, which gives the nutriment consumed daily, and nutriment to dairy products yielded in ten day periods during the first and last sixty-days:

TABLE XXX.—Record of the Jersey Cows During the 1st and 2nd Sixty Day Periods.

FIRST 60 DAYS				SECOND 60 DAYS			
10 Day Periods	Nutriment Daily	Nutriment to 100 lbs. Milk	Nutriment to 1 lb. Butter Fat	10 Day Period	Nutriment Daily	Nutriment to 100 lbs. Milk	Nutriment to 1 lb. Butter Fat
1	22.836	52.17	12.25	7	23.279	55.81	11.92
2	22.960	51.65	11.83	8	22.945	55.85	11.84
3	23.666	52.44	12.05	9	23.629	59.37	12.81
4	23.437	53.92	11.88	10	23.521	60.57	12.08
5	23.372	53.23	11.92	11	22.897	64.25	12.27
6	23.297	54.44	11.80	12	22.922	61.08	11.91
Average	23.261	52.97	11.96		23.199	59.49	12.14

From this table it is seen that during the first sixty days the Jerseys consumed only .062 of a pound more nutriment per cow per day than they took the last sixty days, and that they required only .18 of a pound more nutriment the second sixty day period to produce a pound of butter fat. It is quite probable that during the second period they made the most gain in body weight and that this was the chief cause of the slight decrease in yield to nutriment consumed.

The following table gives the daily average of pounds of nutrients, total nutriment, and the per cent of nutriment in the roughage fed to the cows of each breed:

TABLE XXXI.— Nutriment in Roughage.

BREED	Protein	C. H.	Fat	Total	Per cent
Swiss	1.37	8.92	.41	10.70	39.70
Holsteins	1.87	11.30	.42	13.59	50.48
Jerseys	2.24	9.31	.22	11.77	50.67
Shorthorns	1.32	6.78	.18	8.28	41.13

The following table gives the daily average of nutrients, total nutriment and the per cent of nutriment in the concentrates fed to the cows of each breed:

TABLE XXXII.—Nutriment in Concentrates.

BREED	Protein	C. H.	Fat	Total	Per cent
Swiss	3.54	11.50	1.21	16.25	60.30
Holsteins	3.22	8.77	1.34	13.33	49.52
Jerseys	2.65	8.14	.66	11.46	49.33
Shorthorns	3.02	7.88	.95	11.85	58.87

By these tables it is shown that the Swiss cows received 39.7 per cent of the nutriment from the roughage they consumed, and 60.3 per cent from the concentrates; the Shorthorns received 41.13% of the nutriment from the roughage and 58.87% from the concentrates; the Holsteins received 50.48% from the roughage and 49.52% from the concentrates; and the Jerseys 50.67% from the roughage and 49.33% from the concentrates. That is,

Rowena 2nd, the shorthorn cow that ranked 38th in economy of production of butter fat and 47th in production of total solids.

the Jerseys consumed the largest amount of nutriment in the form of roughage, the Holsteins were a close second, the Shorthorns were third, and the Swiss took the least.

Since the breeds in the contest differed in size, it may be of interest to give the daily average number of pounds of dry matter and nutriment consumed and dairy products yielded by each breed per thousand pounds of live weight:

TABLE XXXIII.—Food Consumed and Dairy Products Yielded Daily per 1000 lbs. Live Weight.

BREED	Dry Matter	Nutriment	Milk	Butter Fat	Solids not Fat
Swiss	28.87	20.28	33.31	1.20	2.95
Holsteins	31.23	20.88	41.45	1.42	3.29
Jerseys	37.61	24.50	43.78	2.04	3.83
Shorthorns	24.48	16.02	28.00	1.03	2.41

SUMMARY OF RESULT.

The records of the cows participating in the St. Louis Dairy Cow Demonstration show that the Holsteins produced daily 53.43 lbs. of milk, testing 3.42 per cent fat, giving 1.83 lbs. of butter fat and 4.24 lbs. of solids not fat. The Swiss cows gave daily 44.18 lbs. of milk testing 3.62 per cent fat, yielding 1.6 lbs. butter fat and 3.92 lbs. of solids not fat. The Jerseys gave 41.51 lbs. of milk testing 4.67 per cent fat, yielding 1.937 lbs. butter fat and 3.65 lbs. of solids not fat; and the Shorthorn cows gave 35.19 lbs. of milk testing 3.68 per cent fat, yielding 1.297 lbs. butter fat and 3.03 lbs. of solids not fat.

The largest yield was by the Holstein, Shadybrook Gerben, that gave on an average 2.35 lbs. of butter fat and 5.17 lbs. of solids not fat, and the second largest yield was by the Jersey cow Loretta D., that gave 2.335 lbs. of butter fat daily and 4.357 lbs. of solids not fat. Of the Swiss cows, Nellie H. produced the largest yield, being 1.75 lbs. of butter fat and 4.363 lbs. of solids not fat; and the Shorthorn cow, 16th Belle of Trowbridge, led that breed by a daily yield of 1.74 lbs. of butter fat and 3.72 lbs. of solids not fat. The milk solids yielded by the Holstein cow Shadybrook Gerben during the 120 days were equivalent to the food value of two steers weighing 1000 lbs. each, and the total milk solids yielded by the 70 cows was equivalent to the food value of 70 fat steers weighing 1405 lbs. each.

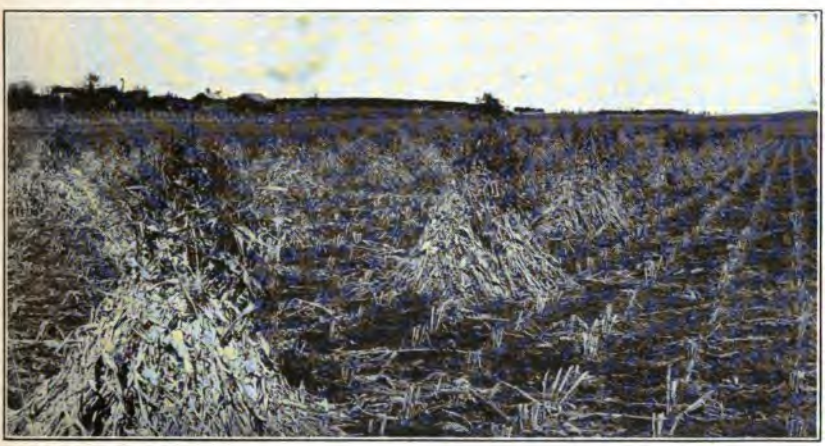
With reference to economy of production, the Jerseys returned a pound of butter fat to 12.051 lbs. of nutriment consumed; the Holsteins used 14.839 lbs.; the Shorthorns 15.52, and the Swiss 16.919 lbs. to a lb. of butter fat. There are physiological reasons for the difference in nutriment required by these breeds for the production of a unit of butter fat. Primarily the discrepancy is caused by the fact that the relation between fat and solids not fat differs in the various grades of milk. As a general proposition, milks carrying a low per cent of butter fat carry relatively more solids not fat than is the case with milk containing

a higher per cent of fat. Taking, for example, the daily average yield of butter fat and solids not fat by the four groups of cows under review—the Swiss cows yielded daily 1.6 lbs. of butter fat and 3.92 lbs. of solids not fat; that is, to 1 lb. of butter fat they yielded 2.45 lbs. of solids not fat; the Shorthorns yielded 2.33 lbs., the Holsteins 2.31 lbs., and the Jerseys 1.87. It stands to reason that cows cannot produce 1 lb. of butter fat and 2.45 lbs. of solids not fat with as little nutriment as 1 lb. of butter fat and 1.87 of solids not fat can be produced.

It appears also that the great bulk and weight of green forage fed to the Swiss and Holstein cows called for the expenditure of an abnormal amount of energy in its mastication and passage through the digestive tract. For, after making due allowance for the nutriment required for maintenance, for milk production, and for gain in weight, the daily average of nutriment not accounted for was, by the Swiss cows, 5.889 lbs. per cow; by the Holsteins 3.688 lbs.; by the Jerseys 2.121, and by the Shorthorns, .725 of a lb. The larger waste by the first two is probably partially due to the weight and bulky character of the feed, and with all, except possibly the Shorthorns, because of a daily nutriment supply in excess of their powers of assimilation. It is quite probable that the amount of nutriment allowed daily for maintenance was in excess of the amount actually used, and that the daily loss or waste of nutriment may have been even greater than the amount calculated.

Second, the Swiss cows had to support bodies weighing on an average 1329 lbs., the Holsteins 1289 lbs., the Shorthorns 1257 lbs., and the Jerseys 948 lbs. Other things being equal, the larger the body, the more nutriment is diverted to maintenance, and proportionally less is available for dairy products.

Third, small cows consume relatively more feed and produce more dairy products than large ones. The Jerseys, per 1000 lbs. live weight, consumed daily on an average 17 per cent more nutriment than the Holsteins, 20 per cent more that the Swiss and over 50 per cent more than the Shorthorns; but they returned 43 per cent more butter fat than the Holsteins, 70 per cent more than the Swiss, and 100 per cent more than the Shorthorns.



Heap high the farmer's wintry hoard,
Heap high the golden corn!
No richer gift has Autumn poured
From out her lavish horn.

JOHN GREENLEAF WHITTIER.

LETTER OF TRANSMITTAL.

MINNESOTA AGRICULTURAL EXPERIMENT STATION,

ST. PAUL, MINN.,

FEB. 11, 1908.

SIR,—I have the honor to transmit, herewith, an article entitled "Corn Breeding in Minnesota." This article contains the experience and results of several years' work in corn breeding at the Minnesota Experiment Station and in co-operation with farmers throughout the state. The work has been under the supervision of Mr. C. P. Bull, Assistant Agriculturist, who has compiled the data and prepared the manuscript.

I would recommend that this article be published as an experiment station bulletin.

Respectfully,

ANDREW BOSS, *Agriculturist.*

E. W. RANDALL,

Dean and Director.

Table of Contents.

	Page.
Possibilities in Minnesota	177
Lack in uniformity and type	179
Pollination and formation of ears	180
Nature of pollination	182
Formation of ears	192
The breeding of corn in Minnesota	192
Number of ears on stalk	196
Factors which influence yield	197
Influence of environment on quality	199
Principles of breeding	200
Foundation stocks	202
Foundation plot	203
Selecting ears	203
The breeding plot	208
Numbering the centgeners	209
Detasseling	211
Harvesting	211
The registry system	216
Centgener notes—Centgener selection	218
Ear notes—Ear selection	223
Selecting kernels for planting	227
The pedigree	229
Pedigree chart	236
The score card	237
Score card points	242
Rules and explanation of points	243
Recapitulation	252
Fourteen years' experience	255

PREFACE.

The demand for information upon the subject of corn has increased rapidly in Minnesota in the past decade. Cultural methods are becoming fairly well understood, but methods of improving the crop by breeding have been in an experimental stage. In the past five years the Minnesota Experiment Station has been putting into practice a method which has been very satisfactory from a practical standpoint and has produced substantial results. In the following pages the methods are explained and the results given.

In viewing the figures in this bulletin, due consideration should be accorded the short season in Minnesota. It is unsafe to plant corn before May 1st in any part of the state. In the central and northern sections, May 10th to 15th is a practical time for planting. In the fall the crop should be "out of the way of frost" by September 1st. The season for growing and maturing the crop is, therefore, very short, and the yield per plant can not be expected to reach the proportion attained in the corn belt states. The soil at University Farm is not kept in a high state of fertility and is on this account hardly adequate for extraordinary yields of corn. An ear of corn eight or nine inches in length and six to six and one-half inches in circumference, yielding eight to twelve ounces of well cured, shelled corn is considered a good standard for most parts of the state.

The work outlined in this bulletin has been made possible only by the hearty co-operation of those in the Agricultural Division. Acknowledgments are due Professor Andrew Boss, Mr. A. D. Wilson, E. C. Parker, and

L. B. Bassett, for valuable suggestions; Mr. Alex Carlyle, Lee Alexander and John Scott for carrying out the details of the field work; Mr. H. D. Ayer for the excellent work with the camera and Mr. Dana W. Frear for the charts and drawings.

It is hoped that the work may prove valuable in offering suggestions and a method by which corn can be improved in yield and quality.

Reprint of Bulletin No. 107 of this Station.

CORN BREEDING IN MINNESOTA.

C. P. BULL.

POSSIBILITIES IN MINNESOTA.

Corn breeding in Minnesota is yet in its infancy. There have been very few men who have appreciated the gain that may be achieved by thought and time judiciously spent in selecting seed for their future corn crop. The few who have, however, are now reaping their reward—1st, in yield, and 2nd, in maturity and 3rd, in the assurance of a crop annually.

Conditions in this northern latitude, especially north of the 45th parallel, are such that one must observe closely two factors. These are early maturity and yield of shelled corn per acre, and they are opposite in behaviour. Early maturity is obtained at an expense of yield and yield increases as the maturation period lengthens. Obviously, there is a maximum in each case; and it becomes the breeder's problem to get the two together in "the happy medium" at the nearest possible point to the maximum. The past years of experience in growing corn have shown that the crop is being better and better adapted and will be grown in increasing amounts in the future.

Experiments carried on at University Farm and elsewhere show many evidences that corn is very much influenced by environment. There are now about six varieties of dent and four varieties of flint corn that may be successfully and profitably grown in the state. There are also many local types of corn that have been acclimated to their immediate conditions. Their breeding, however, has been for the most part neglected. Their origin, in some instances, trace to varieties brought from Iowa, Illinois, Indiana, Ohio and other states. By following the example of Chapman, Riley, Leaming and others, any of these local types can be made highly productive. The characters can be fixed and a variety secured that will be recognized as

standard and superior for the particular locality in which it originated. In this work it is best to strive first for maturity, second, for yield and leave the so-called "fine points" as an unessential quality until the intrinsic qualities have been secured.

Minnesota is a large state and the variation of conditions north and south, will have much to do in shaping the corn breeding policy of the man who undertakes it. In the extreme north section a variety to succeed must normally mature in 90 to 100 days. In the central section from 100 to 110 days may be relied upon for a corn season. In the southern section a variety requiring 115 days for maturing is generally safe. In the extreme northeastern part of the state the soil, water and climatic influences are such that a 90 day corn is hardly safe.

For each of these sections a profitable yield is imperative. The farmers of the southern and central parts of the state can make corn profitable by growing it for a grain crop. The northern sections will for the most part have to be content with growing it as a fodder crop for stock and as an aid in putting crop rotation into practice. Many farmers have by persistent effort succeeded in adapting varieties, such as Pride of the North, Small White Cap, and some of the Flint corns to their local needs and are now growing profitable crops of corn as far north as the 48th degree. It is confidently expected that within a reasonable number of years corn will be a safe crop in nearly all parts of Northern Minnesota.

The farmers, for the most part, will have to do the pioneer work in breeding varieties suited to local conditions. The Experiment Station at University Farm is to work out the principles of corn breeding and discover promising varieties but in the remote parts of the state the work must be cooperative between the farmer and the Experiment Station. Seventeen such cooperative stations have been located in varions parts of Minnesota.

There are opportunities for many corn breeders in the state. One breeder in each township would not be too many. The thousands of acres planted annually to corn creates a great demand for seed since it is only one farmer in many that saves his own seed.

LACK IN UNIFORMITY AND TYPE.

From the fact that farmers have been glad to get corn of any kind, so long as it would mature a crop, the corn of Minnesota is deficient in uniformity and type. The most of our corn shows inconstancy in color of the corn and the cob, or a tendency toward flintiness. Dark and light shade kernels, red and white cobs, ears with tips or butts poorly filled and kernels round and small are not uncommon in the best of our varieties. All this shows lack of breeding. It cannot be remedied in a few years, but can be greatly improved by one year's selection and breeding.

Corn, perhaps, more than any other crop, will deteriorate if unselected and revert to the original types. These original types are best represented by some of the flint varieties and the so-called "squaw corn." The kernels become rounded, flinty and small, the ears get smaller in circumference, the number of rows decreases as does also the yield per acre. While the lack of uniformity and type does not necessarily mean that the production is thereby less, it does mean that the corn is poorly bred and that without "breeding" a variety will not do all that it has the power to do.

POLLINATION AND FORMATION OF EARS.

Corn is an open fertilized plant and is monoecious and diclinous in flower character, i. e., staminate (male) and pistilate (female) flowers are borne separately upon the same plant. The habit of cross fertilization is so firmly established that is is seldom or never that a self fertilized ear produces strong good yielding progeny.

Fig. 1.—A single (male) flower of corn much enlarged. The three anthers are just pushing out of the glumes and have split open at the apex to let the pollen out to be scattered by the wind. There are hundreds of these flowers in each tassel. The pollen grains are barely large enough to be seen with the naked eye.

Cross fertilization is the term used to express the act of the fusion of the pollen (male element) of one plant with the ovule (female element) of another plant.

The improvement of corn, as well as other crops, is very closely correlated with the nature, time and method of pollenation of the plant. It is a well known fact that the development of ears upon the stalks of corn is dependent upon the pollination of the silks and subsequent fertilization of ovules ("seeds") borne on the placenta (cob).

Fig. 2.—½ natural size. Five (female) flowers taken from an ear of corn. These were taken before they were fertilized. The kernels, (A) have not yet taken on a regular form. When fertilization takes place the pollen grain alighting upon the end of the silk (stigma) "germinates" and sends a tube down the stigma to the ovule (A). Here the two elements fuse. From this fusion the growth of the kernel takes place.

Characters are those physical features of a plant or animal that are distinct from other features. The transmitting of characters from parents to offsprings has long been recognized, but the governing laws are but dimly understood. The exact agents of transmission are not known. It is quite commonly accepted, however, that the chromatine coil of the nucleus has much, perhaps all, to do with it. The particular "character transmitting" bodies have been theorized by Weisman and others of his school as "ids." Others have held still different views, but be that as it may, it is enough for practical purposes to know that characters are hereditary and some (desirable or undesirable as they may be) are apparently stronger than others.

NOTE.—Ids are designated by Weissman as infinitesimal bodies which are in all parts of the body. Some of these are constantly moving to the reproductive organs, thus carrying with them the power of building up in the offspring that particular part of the body from which they come.

Gregory Mendel, Abbot of Bonn, (born 1822, died 1884), was the first to throw light upon fixed laws of inheritance. It was not, however, until 1902, (when the law was simultaneously rediscovered by two European scientists), that the laws were given universal consideration. Since 1902 this so-called "Mendel's Law" has been many times corroborated by experiments with both plants and animals. Briefly, the law is the mathematical accuracy with which *unit characters* are transmitted.

To the practical breeder this law is not likely to prove of much value. His breeding work will, for some time to come, be a matter of straight selection rather than creating hybrids from which to select new types. The making of hybrids, selecting hybrid types and testing their comparative worth is, for the average breeder, too long and expensive a line of work. Such work should be the duty of experiment stations, where there should be ample funds and men, whose business it is to know the various laws of nature and to take advantage of such laws whenever possible.

The first study in applying Mendel's Law is to recognize which are unit characters and to discover which are dominant and which are recessive.* Unfortunately, to do this, the plants must first be grown. The scientist should be the one to work these facts out. Once established, it becomes an art to put them to pracical use. And the farmer may become as adept in this as the scientist.

NATURE OF POLLINATION.

In 1903 an experiment was conducted to gain information concerning the pollination of the ear of corn. For this purpose fifty (50) ears of equal age were covered with paper bags a few days previous to the appearance of the (stigma) silks. These ears were examined from time to time and as the silks began to appear the bags were removed from twelve of the ears for about one-half day.

NOTE.—Unit characters are those characters which are transmitted from parent to offspring as a whole or in part and are not influenced by environment, in other words, entirely hereditary. Example—horns of cattle—color of hair—beards of wheat, etc.

NOTE.—Straight selection designates the simple process of selecting the best plants from any variety without hybridizing or changing the general characteristics of the variety.

*NOTE.—Dominant when they show themselves in full strength in the offspring.

Recessive when they do not show themselves in the immediate offspring but do appear in subsequent generations.

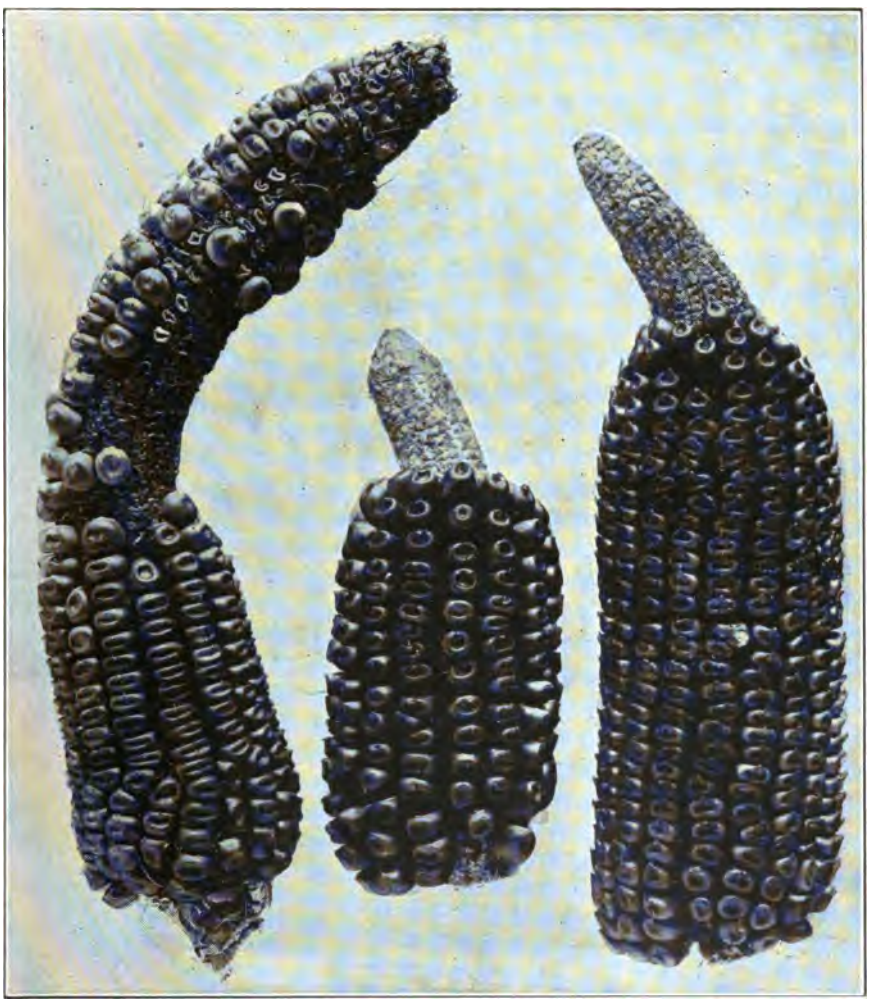


Fig. 3.—Three ears resulting from the first uncovering which was from one to three days after first covered. The ear on the left seems to have been very strong in sending out the silks as some seeds are formed in the middle of the cob. For the most part, only the kernels at the base of the ears are developed; thus it must follow that only those silks had appeared at the time of uncovering.

These ears were then covered and left until harvest. Later when more silks had made an appearance the bags from twelve other ears were removed for a half-day, then covered and left until harvest. Again when it was thought

Fig. 4.—Ears which represent the type of those harvested from the second uncovering which was from three to eight days after covering. From these it will be noted that the silks from the base of the ear have remained receptive and those from the middle have all appeared while those from the tip had not come out.

that all the silks had come out the bags from twelve other ears were removed and replaced as in the other cases. The

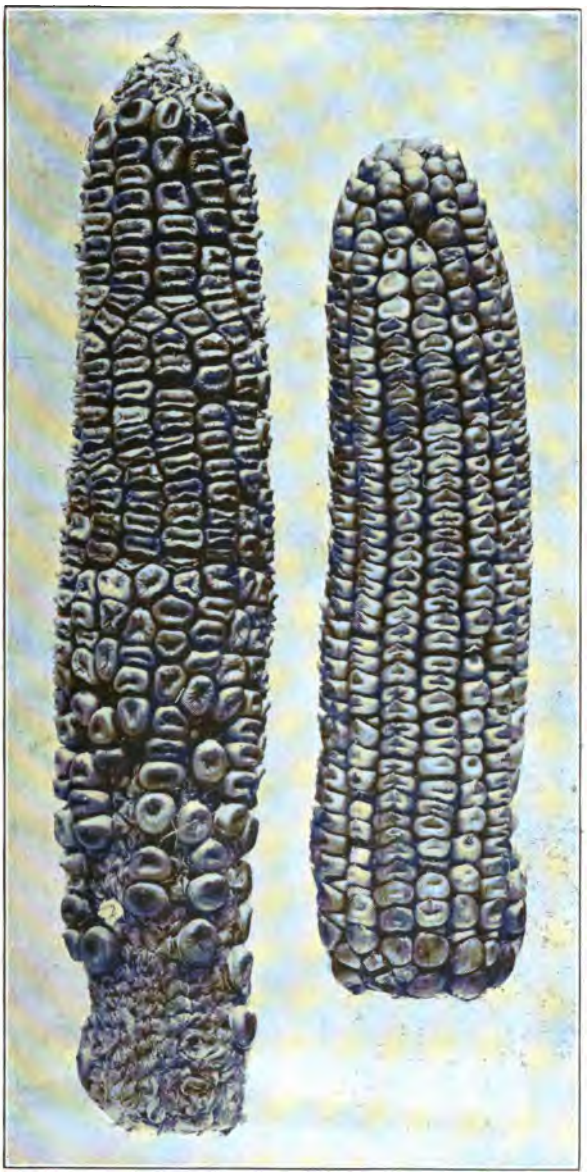


Fig. 5.—Two ears representing those harvested from the third period of uncovering which was from six to ten days. The one on the left better represents the point since the silks from the base have not functioned and have left the cob bare. The right hand one was more even in the time of sending out the silks and is, therefore, filled (imperfectly) at the base. The tips are also perfectly filled.

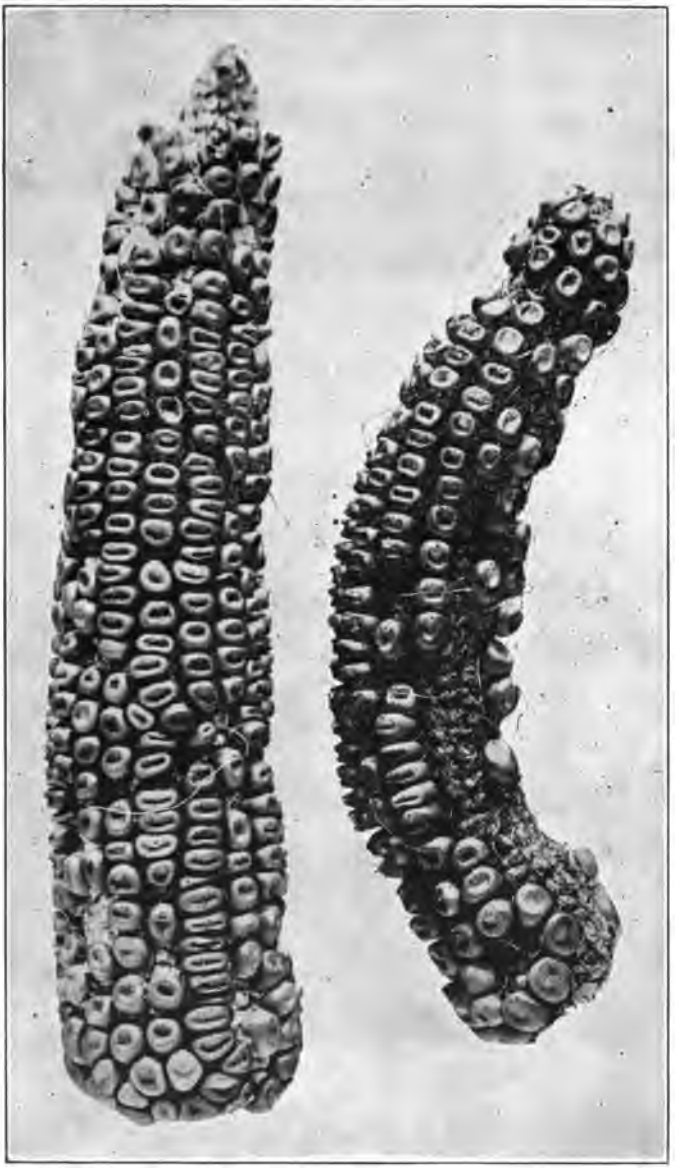


Fig. 6.—The bags were left on these ears for several days after those shown in Fig 5 were removed. They show a remarkable strength or vitality of the ovules and silks. Most of them had succumbed because of no fertilization, but a few remained active.

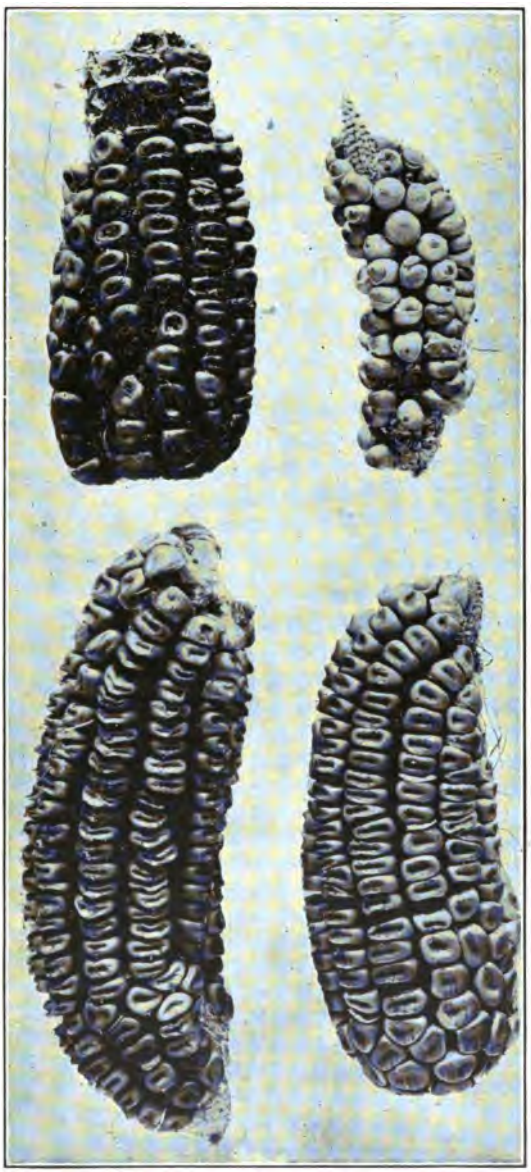


Fig. 7.—Four ears harvested from those covered and left for longer or shorter time. They illustrate the very questionable conditions for the reception of pollen and the chance of receiving a supply of pollen.

bags were left on the remaining ears for several days, then removed, and left off. The ears produced as a result of the different dates of fertilizations are herewith shown in Figures 3, 4, 5, 6 and 7.

In studying the ear of corn in this way it was found that there were relatively three stages or periods of pollination; that the ears differed in the relative number of silks sent out during the different periods, and that the silks remain receptive for a number of days. These periods are not discontinuous with each other but merge, one into another. Nature has provided that the silks should appear from out the end of the husks and become receptive at exactly the same time that the anthers ripen and shed their pollen; thus the pollen falls or is carried by the winds from the tassels to the silks where the fertilization of the ovules is accomplished. In this process nature has, also, provided that the shedding of the pollen and the protrusion of the silks be not out of proportion, i. e., the pollen should not all be shed nor the silks be sent out at one time to insure complete fertilization. A few silks from the butt of the ear come out first and are pollinated by early maturing anthers, which shed pollen several days ahead of the "main crop." Later, depending upon the weather, the silks from the central portion of the ears appear. At the same time there is what may be termed "full-bloom" of the tassel. Some days after this stage the silks from the tip of the ear appear and receive pollen from the few belated anthers yet possessing pollen grains. This insures, for all practical purposes, a perfect pollination.

This feature is a very important one in corn breeding and has much to do with that character of the ear called *uniformity* of kernels. Uniformity of kernels influences, markedly, the planting and subsequently the stand of the field of corn. Without going extensively into a discussion of uniformity here, suffice it to say that no planter will always place the same number of kernels in all hills unless the seeds be of uniform shape and size.

In addition to uniformity, it has been found by germination and strength tests that the middle kernels of the ear possess greatest vitality and producing power. It would seem therefore, advantageous to have the middle form and

type of kernels approach as near the ends of the ear as possible. To do this careful selection must be made, and it is here that the influences of pollination bear.

It would be impractical to examine the tassels of all stalks of corn to discover which ones had the shortest preliminary and shortest final (or the first and third) pollinating periods. In other words, the ones that came nearest to bearing the pollen all at one time.

It is practical to select ears that bear kernel uniformity farthest toward the tips and butts. It is from this point of view that improvement in his line can be secured. The fact that the kernels are uniform is evidence that all were fertilized at nearly the same time and that the first and last periods of pollination were short. Such characters are transmitted from parent to offspring.

Another reason for desiring short tips and butts, caused by short (first and third) periods of pollination, is because the kernels from these are comparatively weak, probably from one reason at least, viz.—the first pollen and the last pollen is not strong and vigorous. We do not know but what there may be a premature or a retarded ripening of pollen because of some physiological reason and it may have been injurious to the pollen; hence the advisability of not using tip and butt kernels and of getting the largest number of kernels fertilized at the same (the second period) time, presumably, when the strongest of pollen is being shed.

By selecting, year after year, those ears which have the fewest tip and butt kernels, the breeder will quickly secure uniformity. Uniformity of an ear is evidence to show that the silks of that ear appear almost simultaneously and are pollinated at practically the same time.

NOTE.—Experience in crossing and hybridizing plants has shown that weather conditions have much to do with the fertilization of flowers. Briefly stated, it was found that normal conditions are those of sunshine and warmth. A heavy dew or a foggy atmosphere will retard the progress for several hours, but upon the appearance of the sun the process seems to literally burst into operation. The usual time for fertilization is in the early morning from sunrise to ten o'clock. There are some exceptions to this rule, where it occurs in the early evening about five o'clock.

The normal period of fertilization may be delayed by adverse weather conditions, the flowers instinctively holding their progress until the coming of bright weather. If the adverse weather conditions are of long duration, the sex elements may lose strength and when finally forced to proceed make a very poor showing by imperfect fertilization. It is worthy of note that the stigmas will remain receptive for several days if fertilization is withheld.

Just how much loss may be laid at the door of these factors is difficult to state, but it is probably due to this weather effect upon the fertilization of flowers that we have poorly filled ears of corn and heads of grains.

Fig. 8.—A cob which, for some reasons, failed to develop kernels. This shows some physiological weakness. The pollen from stalks producing such ears is likely to transmit this weakness.

Fig. 9.—A developing ear of corn with husks removed from one side. Taken just as the silks have started to develop.

Fig. 10.—An undeveloped ear taken from a barren stalk. Elsewhere in this bulletin it is stated that such undesirable features are hereditary and are, therefore, objectionable. Note that no silks have been formed.

FORMATION OF EARS.

As a sequence of pollination comes the formation of ears. The ovules at the butt of the ear are fertilized, first, perhaps incompletely because of scarcity of pollen and imperfectly, because of weak inception. This fact, together with the position and condition within the husks at this point can make at best only imperfect kernels with dwarfed, malformed germs. At the opposite end, the tip of the ear, we again find that there is imperfect and incomplete fertilization of ovules, even to a greater extent than at the butt. In addition to this, the silks are the very last to appear and, therefore, receive the belated pollen, which may be weak. As a result, the kernels formed at the tips are not only imperfectly formed with dwarfed, stunted and malformed germs, but the kernels themselves are dwarfed and deficient of plant food. In developing it is essential that the ear mature regularly and with perfectly formed kernels. One cannot tell what the crop may bring forth, but from the fact that some ears are well formed and others poorly formed and from the fact that these characters are transmitted, it stands to reason that selection along proper lines will greatly remedy the condition of the succeeding crop.

THE BREEDING OF CORN IN MINNESOTA.

Breeding plants of any description or for any purpose is a fascinating work and is a profitable vocation if one wishes to make it such. For Minnesota conditions early maturity is all important and comes first and perhaps at the expense of yield. These two characters, earliness and yield, must be the aim, and any correlative character should be closely studied.

In every field, or measure of any kind, there is always one plant that is superior to all the rest in at least one regard or character. It may be weight of ear, length of stalk, size of leaves, the per cent of corn to ear or the prepotent power to yield, but one individual will always exceed the rest. One has but to choose the character, then arrange the plants according to the measure of this character, and the superior plants will be prominent. Since

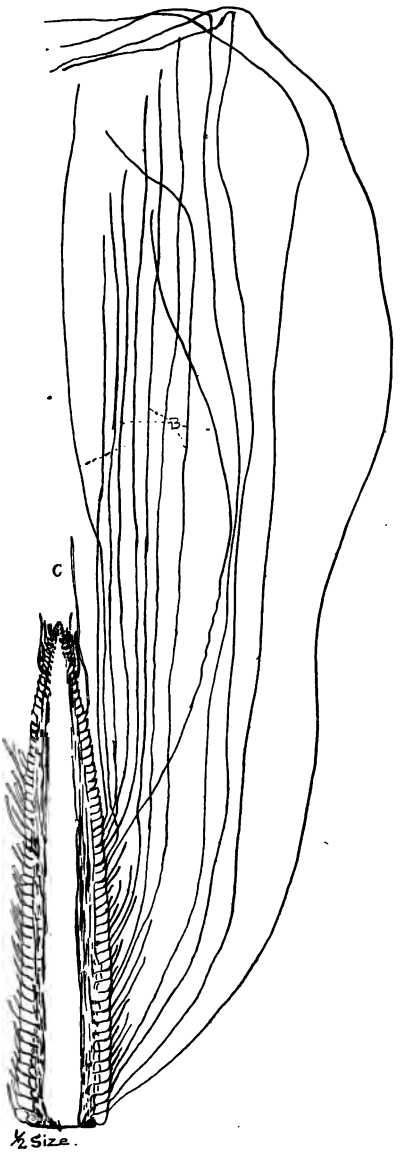


Fig. 11.—The above cut shows a longitudinal section of an ear developed upon a stalk 75 days from planting time. A few silks (stigmas) are shown coming from kernels at the butt (A) middle, (B), and tip (C), of the ear. Note the comparative length. Those marked A were just appearing from out the silks when the ear was taken.

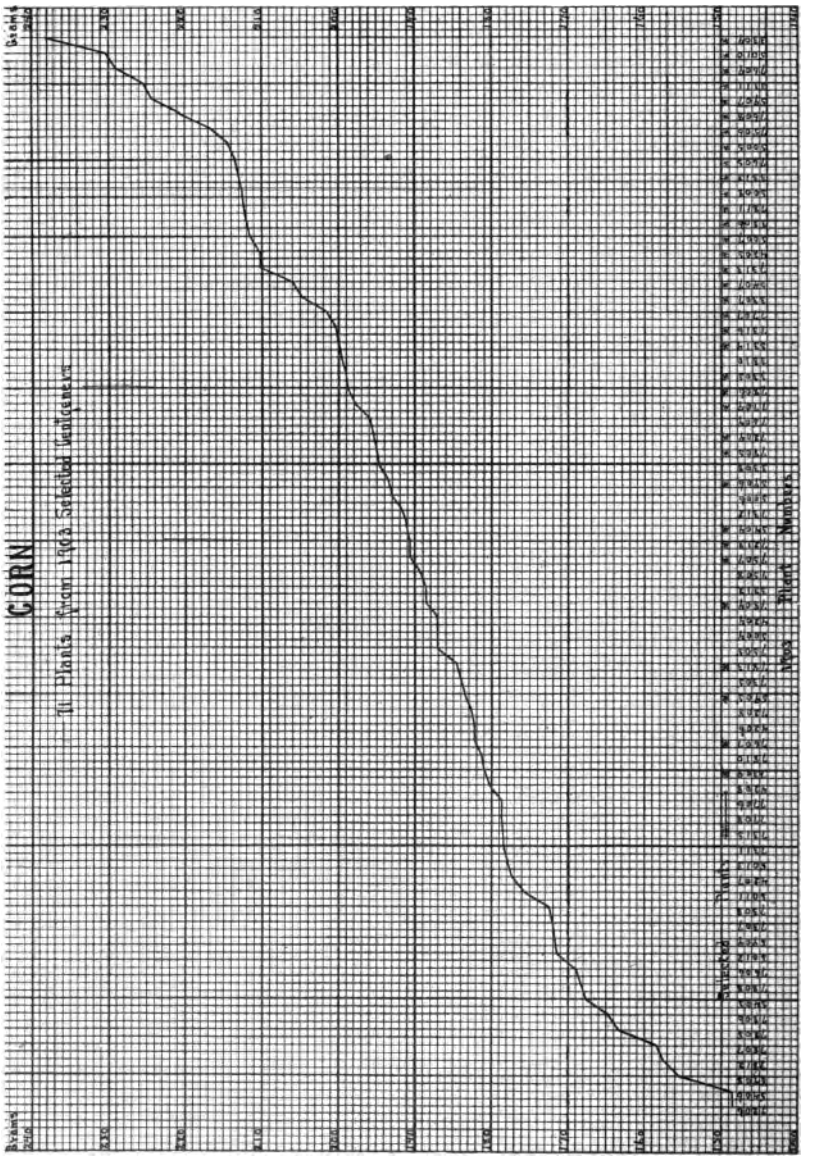


Chart I.—A "Quetelett Curve," of the plant yields arranged from left to right according to amount. The yields are expressed in grams on the right and left. The plant numbers are given below. Those checked with a star are the selected plants. In making selections from selected centgeners it has always been thought wise to save at least one from each centgener; more from the best and less from the poorer ones. This is made necessary from the fact

that only a limited number of centgeners can be handled. Thus there appears to be a little irregularity in the selection. It will be observed, however, that of the 25 highest yielders only one is left out. Other notes also have an influence in the selection.

Quetelett is the name of the man who first conceived the idea of plotting characters in this way.

the yields and maturity interest us most in Minnesota, the largest mature ears, provided they have a high percentage of shelled corn to the ear, should be selected.

The accompanying chart will serve to illustrate that there are always a few best individuals and one which is superior to all. Major Hallett in England in 1858 deduced this fact when breeding wheat, and summarized it when he said, "In every field there is one best plant, in the best plant is the best ear, and in the best ear a best seed."

Breeding by selection is in effect nothing but an elimination of poor inheritance and thereby giving prominence to those individuals possessing strong inheritance of desired qualities—in other words, prepotency. From this it may be properly inferred that all plants do not possess equal inheritance and such, in truth, is the case. The greater number of plants of a common crop are not strong in producing power. It is here that the breeder takes advantage of his opportunity and by eliminating the weak, permits only the strongest to produce.

In the process of selection the ear row-test or centgener must be taken as the basis, and the performance of the progeny must be taken as the standard rather than any record of the individual mother plant or mother ear. The plant, as well as the ear, depends upon environment, culture and heredity; hence, undue consideration may be given on account of environmental influences (sunlight, soil, etc.,) and culture when the intrinsic worth is below the average.

Accuracy and precision are essential to the best of judgment that the breeder distinguish between the accidental and the real. The test should continue over at least three seasons of growth for it very often happens that a centgener from a single plant does well the first year, but gradually decreases during the following year.* For the

Centgener, a word devised to designate the small plot or row of plants resulting from the seed of one mother plant.

*NOTE.—This point is illustrated in the pedigree chart on page 234. It will be noticed that centgener 12501 yielded more than 12701, but its power to yield in sucessive centgeners was inferior to 12701 which grew stronger year after year.

The writer believes, therefore ,that it is not advisable to confine the selection, from centgeners grown in the foundation plot test, to too small a number of individuals. A breeder can better afford to carry along a few less worthy in order to be certain that he has the one that is best.

present breeding in Minnesota must be confined to the securing of yield, but sooner or later type must become an important consideration. The time is coming when standard varieties will be recognized among field crops as they are now recognized among breeds of live stock. Our systems of breeding are destined to become more or less changed, but for the present a simple method will bring largest returns.

Coincident with methods of breeding are germination tests and such records as will enable one to make a comparison of centgeners and ears. With these data well tabulated a breeder will hardly make a mistake in selection.

Number of ears on Stalk.—It is not at all uncommon to find two ears on one stalk of corn. Whenever a farmer finds these he instinctively makes a mental note of the fact that he wishes every stalk had two stalks. But as

Fig 12.—Two ears growing on one stalk. The upper one is the normal one. The lower one is the accidental ear, such as occasionally is found in every corn field.

much as we should like to grow two ears per stalk, there never yet has been produced a variety of dent corn that would consistently produce two ears per stalk. So far as known the practicability of breeding a two eared variety has not been proved.*

In 1897 the Minnesota Experiment Station started breeding plots upon the centgener plan with a view to establishing, if possible, two eared varieties. The foundation stocks of these plots were Minnesota No. 13 and Minnesota No. 69, both good yielding, vigorous, local varieties. The plan of the experiment was as follows.

From the crop of 1897 several plants bearing two ears were selected. The better of the two ears was selected from each stalk. The seed of these produced the centgeners in 1898. In 1898 notes were taken as usual upon the centgeners and the two eared plants marked. From these again the better ears were selected for 1899. This selection and planting continued until 1900.

In 1899 Minnesota No. 69 was discontinued because of failure to produce strong two-eared plants of sufficient number to warrant further trial. In 1900 there were but two centgeners of Minnesota No. 13 in which two eared stalks could be found, and in these only a few were two eared. This experiment was then discontinued. It will take more than two such trials to bring definite results and determine the practical value of establishing a two-eared variety. The results obtained, however, bear out the idea, that two-eared stalks are not normal in well bred dent corn. Such "happenings" are physiological and bear little or no part in corn breeding principles.

FACTORS WHICH INFLUENCE YIELD.

In considering the yield of corn in Minnesota there are a number of influences which one must take into consideration. The immediate field conditions such as soil, drainage, etc., will vary with nearly every farm or part of the farm. There are a few things, however, which, in a general way, determine the character of the crop produced. The

*In this connection it is interesting to note that in the history of the corn plant ears and branches are budded at every joint. In "degenerated corn" these buds often develop but never from what is known as good corn. In figures 13 and 14, page 198, stalks of corn are shown with the leaves off. In these the buds are apparent.

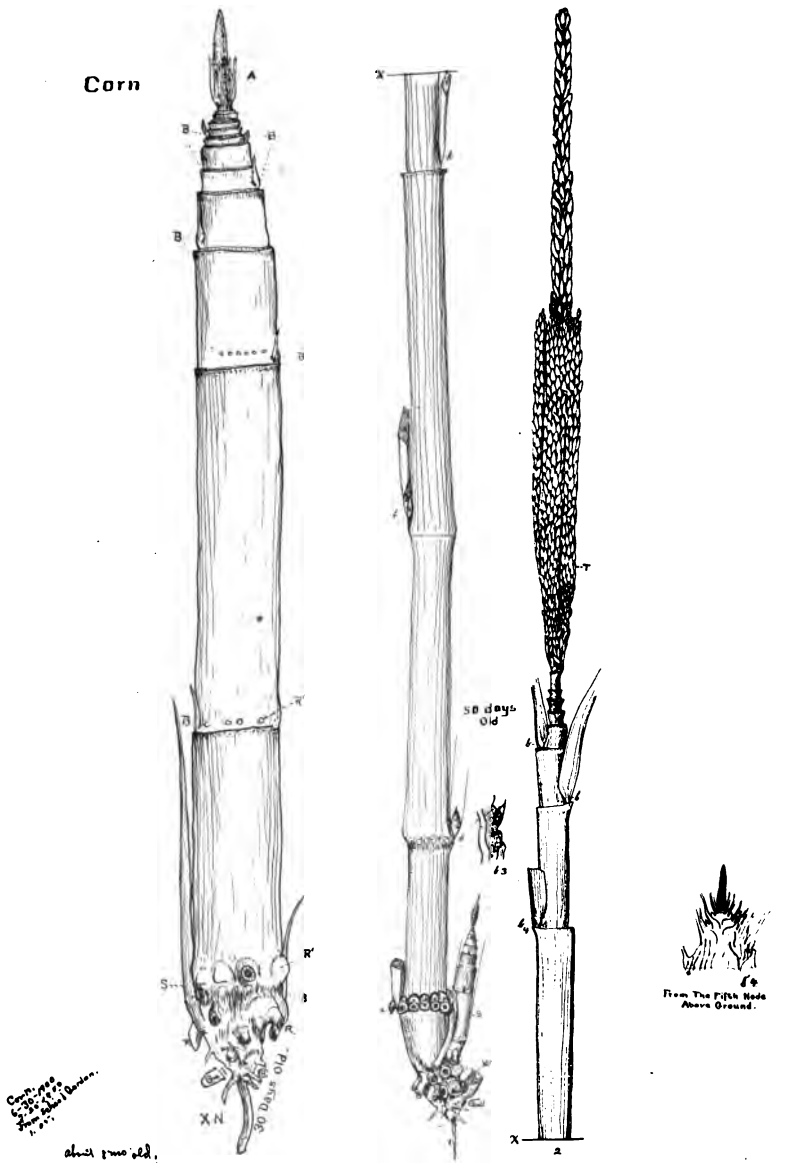


Fig. 13.—A stalk of corn one month old with the leaves removed. (A) tassel where male flowers are borne; (B) rudimentary buds of ears and branches of which only one develops on ear, (R) roots, (R') root buds—often called "brace-roots," (S) a branch or "sucker." Note that there is a bud at each joint.

Fig. 14.—A corn plant fifty days old with leaves removed. At this age the tassel was just pushing out. (1) shows the root area and the first three joints above ground. (a) is the first whorl of aerial (brace) roots. This

marks the ground line also. (b) rudimentary buds which seldom develop. (b3) the bud on on (b) enlarged to show the rudimentary branch of the bud. (2) the upper part of the stalk bearing the tassel, (T) and the ear (b4). At (b' 4) the ear bud is enlarged and shows the tiny ear and the husks. In between the husks will be seen other buds. The presence of these buds bears out the idea that at one time the corn plant was much branched. They also emphasize the fact that the plant should receive no "set-back" in its development. If it does, a stunting of the ear is sure to follow.

fertility of the soil, the water supply, the texture of the soil, the preparation of the seed bed, insects, diseases and the cultivation of the field are potent factors in producing yield and character. More potent than these, however, in stamping quality and quantity upon a field of corn are its hereditary tendencies and its breeding. The care and culture will temporarily increase the crop, but breeding better individuals will make a lasting improvement under all conditions. All living organisms have hereditary tendencies more or less marked. These tendencies may be important or they may be unimportant. It remains for the breeder to distinguish between them, and then, by careful methods of selection give emphasis to the good; thus reducing the poor to the minimum. When this has been done a variety may have what is commonly called "breeding", and this breeding will be apparant at a glance.

INFLUENCE OF ENVIRONMENT ON QUALITY.

To distinguish between the "heredity" of a plant and the physiological and pathological appearances of plants is not often possible. In view of this fact, the breeder to be on the safe side must take for granted that any sign of weakness is a bad sign and avoid selecting anything but the strongest. Poor soil with too much or too little water will tend to produce a weaker plant than one where conditions are congenial but in all probability the strain bred on poor soil will be very much stronger when changed to a rich soil. The type may, by the change, be very altered, for it is one of the arts of breeding to cause variation by an increased food supply. The texture of the soil will also decrease the stamina of a crop. If the seed lays in the soil a long time before it germinates and then the young plant has difficulty in pushing its way to the surface the physical strength of the plant is taxed and its prepotency impaired.

The weather influences during the growing season and at maturing time have much to do in making a large,

bright, strong, well filled seed and ear. A hot wind and drouth or a drenching rain may do a great deal of damage that does not appear "on the surface." A late, prolonged fall with corn "all but matured" will work havoc with germinating power and strength of seed. Corn intended for seed is better off cut and shocked prematurely than left standing until field cured under such conditions. In short, the quicker the corn is matured after it has reached the "dent stage" the better it will be. If quick maturity does not come naturally cut the crop and force maturity.

Harvesting the crop is an important factor in spoiling or retaining such quality as the season has produced. If left in the field after the ears have become "field cured" the taking in and giving off of moisture as the weather fluctuates is likely to do damage. The corn should be husked and stored immediately. The two things important in curing seed corn are free circulation of air and constant drying.

It is not necessary, except in extreme cases, to fire dry corn. It shoud not be encouraged too strongly for there is danger of injuring the germ by too rapid drying.

PRINCIPLES OF BREEDING.

In all lines of production there are certain definite, underlying principles which govern the process. These principles are in some instances fairly understood, but the principles of breeding are for the most part not well comprehended. This is especially true with corn and other lines of plant breeding. With plants one must grow many generations before a conclusion can be drawn and before the conclusion can be declared a certainty.

There are constantly influences, some entirely unforeseen which are not understood or under the control of the breeder as is the case in breeding live stock. In spite of this, there has been a great deal of plant breeding going on, tho perhaps in a very crude way, and some good results have been obtained.

When corn was first discovered by the colonists to be valuable, we are told that the Indians were harvesting and saving their crop for the winter's supply of food. From

this supply the next year's seed was carefully selected by them and kept separate expressly for planting.

The improvement of corn must come from utilizing two natural laws, that are diametric to each other, and yet without them progress would be slow. The "Law of Variation" gives rise to a multitude of fluctuations, offering the breeder his choice and giving with his choice the assurance of the second law—that in spite of variation "Like Produces Like."

The breeder in making selections, does so, expecting that at least to a limited degree, the characters selected will be conveyed to the offspring.

Some plants, as barley and flax offer greater assurance than others that a larger percentage will follow the chosen character. The reason for this lies in the fact that the flowers are close fertilized. Rye and corn are open fertilized and are, therefore, more difficult to reduce to a type. In the former the plants' characters are held practically within itself while in the latter the characters are, for the most part, only half those of the mother plant. The other half comes from the plants furnishing the pollen. The close fertilized plants when selected would be expected to breed true—which they do. On the other hand, the open fertilized plants would be expected to show nearly as great variation as the parents—which they do, but with diminishing degree as the selection proceeds.

It must be remembered that each and every individual seed is a perfect little plant of itself, capable of producing a mature and complete plant. In other words, it is the individual seed and not the ear of corn that is the unit. Each seed, whether from one part of ear or another part, is capable of producing a perfect plant independent of the presence of other plants. The old time idea, that by discarding the tips and butts of ears there would ultimately be produced ears without tip and butt kernels, is still adhered to by some, but has long since been refuted. A man might as reasonably expect that if he did not use the runt pig for breeding, the pigs would cease to have large litters, or by cutting off lambs' tails the succeeding generations would be tailless.

To facilitate the selection of plants according to the above named natural laws, there are necessary a certain

list of "ways and means," data or notes. It is impossible to carry, in one's mind, the individual differences of characters of fifty or more plants. Data arranged in tables, as herein described (see pages 225 and 226) are a necessity. A breeder should aim to take vastly more notes than seem necessary. They will nearly always prove useful.

FOUNDATION STOCKS.

In starting a breeding plot of corn it is important to start as high on the scale as possible. The variety or strain that is best adapted to the locality and will yield the most shelled corn per acre should be secured. Possibly this variety can be found at home or in the neighborhood or in the country. At any rate, a thorough canvass of the local community should be made before looking for corn from a distance. Corn is so thoroughly influenced by environmental conditions, that to procure a variety already adapted is a decided saving of time in securing a suitable variety. There may be conditions under which it would be advisable to get the foundation breeding stock from a distance; e. g., suppose (X) is a variety of corn grown in a remote locality, that has good ears, deep, well shaped kernels and that yields heavily, but is just a little late for the seasons in the new locality. With this one exception, (X) is better than anything of local merit. In this case it would be wise to get this corn, plant it early and by selecting the earliest maturing ears breed it to suit the new locality seasons.

In making a choice of a foundation stock, one should always have in mind an ideal. Some may prefer a white, others a yellow corn. Color is a matter of fancy and does not interfere with what constitutes an ideal, or with quality. An ideal corn is (1) one that will mature in time to avoid frost, (2) one that grows plants of large leafage, strong (not necessarily course) stalks and medium, short ear shanks; (3) one with ears of uniform type and as large as conditions will permit, (4) one with kernels as deep as the length of the growing season will allow. For Minnesota conditions all emphasis should be placed upon the first. Too many farmers are annually "tempting Provi-

dence" by raising a variety that is too late for their conditions, and mainly because they are attracted by a large ear.

Fig. 15.—The Foundation Stock selected ears stored preparatory to curing, final notes and selection.

SELECTING EARS. FOUNDATION PLOT.

After the variety for breeding has been decided upon, plans for the selection of mother ears may be made. In this discussion it will be taken for granted that only bulk seed of the variety can be obtained. The land should be chosen with care and should be of good fertility, good tilth, even in contour, texture and producing value. The size of the plot need not exceed one-half acre in area. The seed

should be hand picked to discard all poorly shaped or otherwise inferior kernels. The soil should be well prepared. The planting should be done the same as with any other field except that the seed should be placed in rows instead of the so-called check method. The rows may be the ordinary distance apart. The seeds in the row should be two per hill and the hills 14 to 18 inches apart. When the

Fig. 16.—The type of ear that should not be selected. It lacks uniformity, maturity and shape. The kernels are too chaffy for Minnesota conditions. Contrast this ear with those in Fig. 17

plants get to be about four inches high the poorer of the two in each hill should be pulled; thus leaving the best plants, and each plant separate from each other plant. In this way inspection is at all times made easy.

When the plants have begun to tassel, the plot should be watched and the barren and weak stalks detasseled. This cannot properly be done all at one time for all tassels do not appear simultaneously. Two or three treatments will usually be sufficient. At harvest time (before any killing frosts) the corn should be cut and shocked in small shocks. When field cured the husking may be done. This, however, may be left for some time. But no freezing weather should find the corn still in the field, for freezing is sure to do some damage to the seed. At husking time or immediately afterwards the first selection of ears should be made, if the corn be one of the local varieties. If the variety be one that will barely mature in average seasons the selection should be made just before harvest. Some ears are earlier than others and may be detected by the drying of the husks. In selecting mark those plants so they may be again found after the corn is cut and shocked. For this first selection about 200 ears will be sufficient. These, later, may be judged according to score card points. They should then be shelled after the following notes are taken.

1. Circumference of ear.
2. Length of ear.
3. Number of rows.
4. Weight of ear.
5. Weight of cob.
6. Weight of grain.
7. % grain to ear.

The selection of foundation mother ears is a very important step, for the greatest progress in breeding by straight selection is made by the choice of foundation plants, if the choice be well made. The remainder of the work is chiefly that of fixing type and characters—a subsequent improvement in yield of course is recognized, but it is slight.

NOTE.—See page 238 for score card.

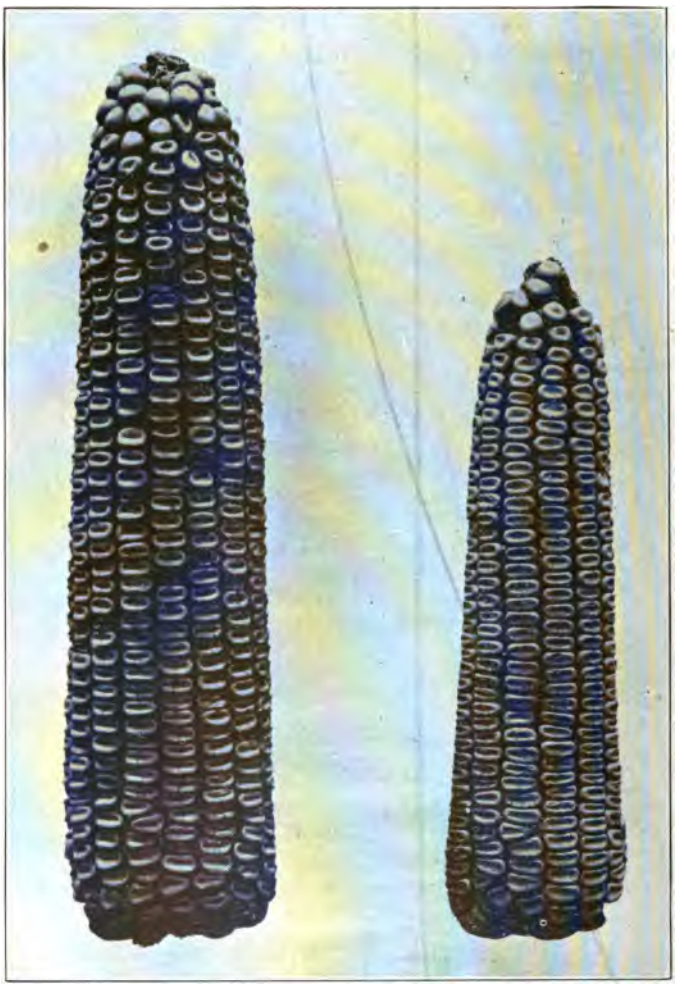


Fig. 17.—Two well formed ears. The smaller ear is of small white capped variety which matures in 100 days and is being adapted to Northern Minnesota conditions. These are the types of ears to be sought in selecting foundation stock mother ears.

With these notes and the score card before one a selection of mother ears for the breeding plot is not difficult, yet a person is often-times required to make a choice between the value of two points; e. g., two ears may in all other respects be equal but may differ in weight of shelled corn and per cent of grain to ear. On general

principles, it is always best to choose those ears that give greatest amount of grain regardless of the per cent of corn. This, however, is not always the case. In other instances, the score card may show an ear to be poor in some respects, while in yield of shelled corn, size, etc., it may stand well. In such a case, preference should be given the intrinsic qualities. Such points as the breed character are not so essential in this case. They can be remedied later.

Fig 18.—Selecting the best ears from the foundation plot. The marketable ears are separated and placed in gunny sacks in the field. These are taken to the laboratory and dumped upon a table. The poor ears are gradually worked off into the baskets while the best 200 or more are laid to one side of the table and afterwards placed on the racks behind the men.

THE BREEDING PLOT.

It must be understood at the outset that the breeding plot is an entirely different and differently managed plot from the foundation plot. Its size will depend on the number of ears finally selected from the foundation plot, but will usually not exceed a half acre for the average farmer. An unwritten law recognizes the value of testing a large number of individuals in breeding. The greater the number the greater the fluctuations of characters; hence the better opportunity for selection. But under most conditions it will not be possible to carry on the work without a limit to the number of individuals handled. For general results the Minnesota Experiment Station has found that 200 plants from a single mother plant is a convenient number with which to work. If the seeds for planting are carefully selected, it is a large enough proportion of seeds from a mother plant to use. The number of centgeners worked with should be 25 at least, and as many more as is convenient to harvest and care for.

The planting demands a considerable amount of foresight. The land, as for the foundation plot, must be uniform in every respect. Any difference in texture, contour or fertility will give results of an incomparable character. Previous to the planting the soil is worked up well with a disc and a harrow to make a fine, firm seed bed. The plot is then marked off in rows the ordinary distance apart. Cross marks (14-18 inches apart) are then made

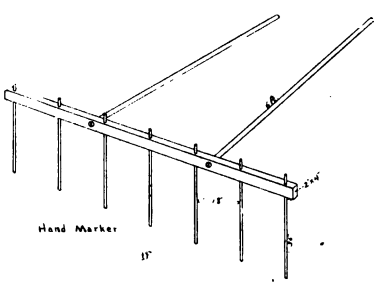


Fig. 19.—A hand marker for marking the cross marks for planting. The markers are broom sticks or some such sticks mounted 18" (14" if so desired) apart in a 2x4 pine piece. The length can be made as desired. The handles are placed equal distances from each end and slanted uniformly toward each other so as to permit an easy grasp when the operator is drawing it.

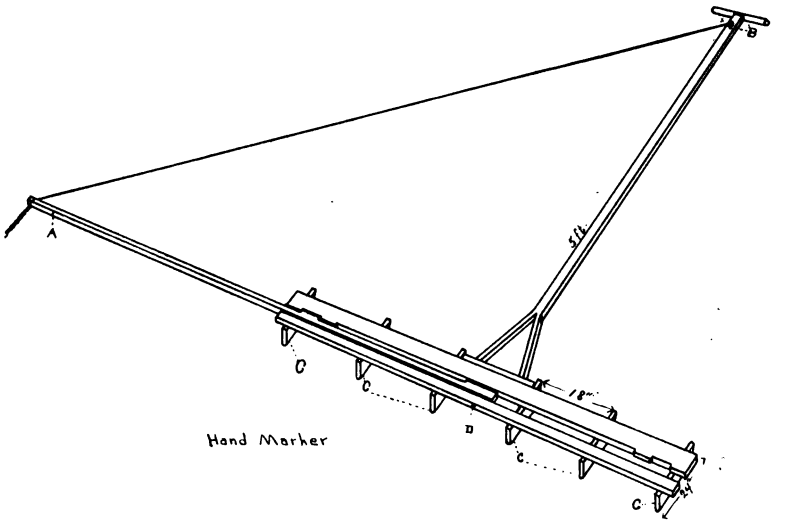


Fig. 20.—A hand marker for marking the cross marks for planting. The runners are made from 1"x6" or 6" or 2" firmly nailed 14" to 18" apart to the frame on top. The frame is made from 1"x6" or 8" and 1"x4". The tracer (A) should be just the length of the marker so the operator can follow the tracer on return trips. A rope from (B) to (A) holds the tracer in adjustment. A bolt (D)permits the marker to revolve readily from right to left. The marker may be drawn by one or two persons.

either with a hand or horse marker. In planting there are usually three or more so-called border rows planted on the edges of the plot before planting the last one. This is done to offset the influence of extra food supply, sunshine, etc., and to create uniform growing conditions for the centgeners. Experience teaches us that the old fashioned method, the hoe, is as quick and otherwise satisfactory as any for getting the seed into the cross marks. If the seed supply will permit, two seeds may, with profit, be planted per hill. The poorer of the two plants of course will be pulled out when the corn stands about four inches high. This gives somewhat of a selection to start with. The time of planting depends upon the seasons, but it is always a good policy to plant as early as the season will permit. This is often as early as May 10th and as late as May 28th.

NUMBERING THE CENTGENERS.—The system of numbering used to designate the various rows or centgeners is the one universally used in the field crop nursery at University Farm. It provides a serial number for each

Fig. 21.—Planting the centgeners in the breeding plot. Two men can do much quicker work than one. After the field is marked out, the stakes are set and the envelopes containing the seed placed in order just as the centgeners are to be planted. The planter makes a depression with his heel and then drops the seeds in place. The man with the hoe follows and places a hoeful of moist soil on the seed and steps on it with the toe of his shoe or presses it firmly with the hoe.

centgeners; *c. g.*, in the centgener number 901 the nine indicates that that centgener is the ninth one, in the corn nursery and the other two places (01) in the number

TABLE XXXIV. Number of centgeners and of plants arranged to illustrate the method of planting, to limit in-crossing within cengeners.

Centgener Number 1907	Plant Number 1906	Centgener Number 1907	Plant Number 1906	Centgener Number 1907	Plant Number 1906
101	212	1601	1509	3101	2909
4501	4408	3001	2613	1501	1308
201	308	1701	1513	3201	2910
4401	4406	2901	2605	1401	1305
301	408	1801	1709	3301	3211
xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
xxxx	xxx	xxxx	xxxx	xxxx	xxxx
1401	1305	2901	2605	4401	4406
3201	2910	1701	1513	201	308
1501	1308	3001	2613	4501	4408
3101	2909	1801	1509	101	213

NOTE.—The centgener numbers in each case trace back to a plant number of the previous year. Thus centgener 101 is planted from seed sown from plant and ear number 212.

The centgeners in each case are in duplicates thus the two rows from the same plant number of 1906 do not appear side by side. In this way cross fertilization is assured.

leaves the chance of giving each plant in the centgener a number. Thus we may have plant number 909, 911, 945, 995, etc.

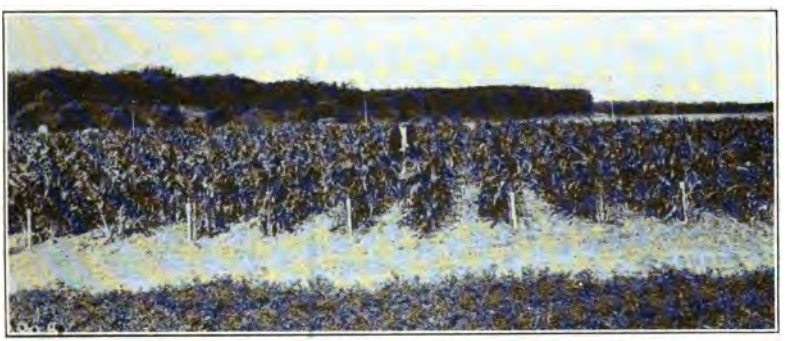


Fig. 22.—The 1904 corn centgeners plot (nursery) at about two months.

DETASSELING is one of the requisites for good breeding methods. By detasseling is meant the pulling out of tassels from the weak and barren stalks.* Such features as physical weakness and barrenness tend toward deterioration and must be avoided. If left to ripen the pollen from these stalks fertilizes the strong ones which may possibly be selected. To remove the tassels grasp them firmly and give a quick upward jerk. This will break them off just above the top joint and do very little harm. As little harm as possible should otherwise be done to the detasseled plants. On this account they should not be cut off or broken out sidewise. Any damage of this sort will influence the yield of the centgeners. In this way a stock may be discarded when otherwise it may possess a strong inheritance and yielding power.

HARVESTING THE CROP.—Some breeders prefer to allow the corn to stand until it is "dead ripe," but for Minnesota conditions the experience at the Minnesota Experiment Station is strongly in favor of cutting and shocking any corn intended for seed purposes. The corn cures very slowly upon the stalk if left standing, while in the shock it will cure rapidly and is in much more

*NOTE.—Barren stalks are those which bear no ears. They may be discovered by the absence of the enlarged leaf sheath just above the joint where the ear should appear. In average fields of corn in the state there are often as high as 10% of barren stalks.

Fig. 23.—A portion of the 1905 breeding plot showing a tendency toward stooling. This feature was very noticeable. It is not, however, an altogether desirable feature

favorable condition to retain its qualities in every respect. On this account the centgeners should be cut and shocked separately before any killing frost. The cutting should be done when the kernels are well dented or in the "hard dough stage." The stalks and leaves are yet quite green at this stage and in the shock there is a gradual and normal filling out or maturation of the ears.

If, on the other hand, the corn is left to mature "on the stalk," the ears and stalk ripen very slowly. This, as has been proved by the seasons of 1905 and 1906 in Minnesota and South Dakota, does much damage to the vitality of the seed. The nursery corn at the Minnesota Experiment Station has been cut before killing frosts each year and has always germinated better and stronger than the field corn which has been allowed to ripen on the stalk.

Fig. 24.—A desirable stalk of corn. Note the height and size of the leaves, the strength and vigor displayed.

Fig. 25.—Weighing the stover from one centgener.

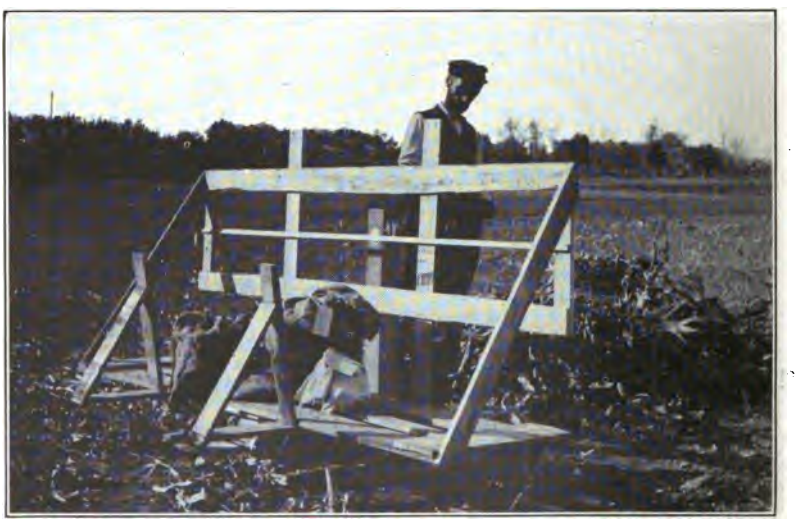


Fig. 26.—Weighing the ears that have been husked from one centgener. The selected ears are in the small bag. The bulk is in the two larger sacks.

Fig. 28.—Selecting the plants from the centgeners as they are harvested. One man takes the notes while another records them. The shocks in the background are the shocks from the harvested centgeners.

Fig. 29.—Selecting the best ears from the best plants. After the best plants have been selected, as in Fig. 28, the best ears are selected from them.

THE REGISTRY SYSTEM.

In all systems of scientific breeding there must be some method by which the stocks may be traced to their ancestry and their identification made known. The system in vogue at University Farm and used in the Agricultural Division was instituted in the early nineties by Prof. Hays, then Agriculturist of the Minnesota Experiment Station. The system is so well adapted to the use of breeders of plants that it applies equally as well to the open fertilized and the close fertilized species. It is used with a few modficatons in corn breeding as follows:

When any new stock of seed is brought to University Farm for field test, garden or nursery breeding plot it is given a Minnesota number. The Mninesota numbers range from one (1) up, in each species. Thus in corn there are Minnesota numbers from (1) to (365). The next one brought will be numbered (366). This becomes the seed's register number in the garden or field so long as it remains in these tests.

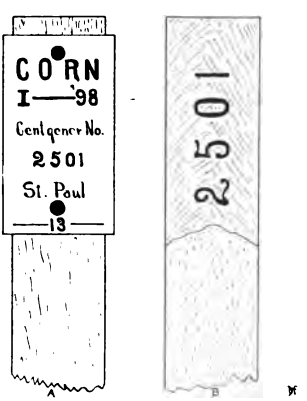


Fig. 30.—Stake labels for designating the centgener rows. (A) is used at University Farm and consists of a three-ply white card printed with India ink, then paraffined with 70 C hard paraffine. These cards are then tacked onto a stake, made of a lath cut in two; these being two feet long. (B) A stake found practical where only one foundation stock is being bred. It is made by whittling off the rough lath ,then marking, with a soft lead pencil or a blue pencil, the centgener number.

When a stock or variety is taken into the nursery and selections made from it the Minnesota number is retained as a check but it is not adequate for the complete registration check or pedigree. An additional check is introduced

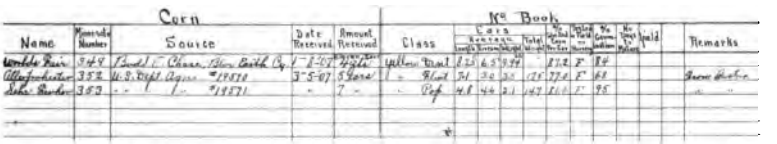


Chart II.—Page headings and partial record of new stock in the "Corn Number Book." In this book are recorded all new and improved varieties brought to the Experiment Station.

and called the "nursery stock number" (abbreviated N. S. No.) and when referred to on paper is written N. S. No. I, '98, 50, '98-102, etc., the I referring to the class of breeding as distinguished from II or IV, the Roman one (I) indicates Straight Selection, the Roman two (II) indicates Hybrids and the Roman four (IV) indicates theoretical or nursery management experiments. The '98 refers to the year in which the breeding stock was started. If it were started in 1907 the N. S. No. would read I, '07. In breeding practice the serial number (50-102, etc. as above) is not given to the variety, as a whole, for the Minnesota number answers for that. The serial number is given to the mother plants selected from the foundation plot. These numbers then hold to all progeny of the original plants. Following this idea it will be noticed that in the pedigree sheet, page 234, centgeners 101-1901 inclusive come from centgeners 12701 of 1902 and, therefore, have the same N. S. No.

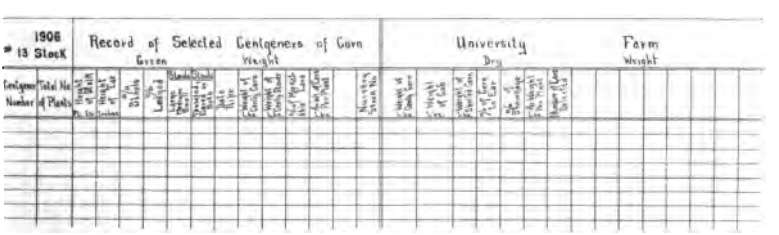


Chart III.—Page headings used in the Corn Ledger Book. In this book are recorded the records of the selected stocks. These headings are used on preliminary sheets which are used in selecting the best centgeners and the best ears from the best centgeners.

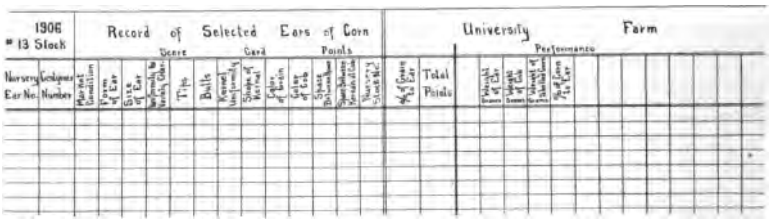


Chart IV.—Page headings used in the Corn Ledger Book for recording the data relative to the selected ears of corn.

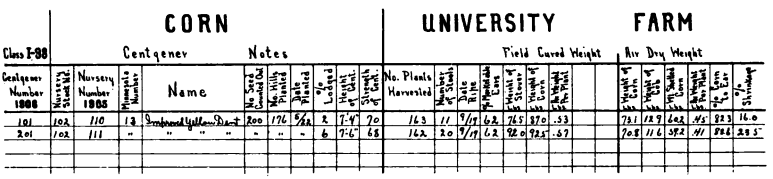

CORN
UNIVERSITY FARM
Class F-88
Centgener Notes
Field Cured Weight
Air Dry Weight
Centgener Number 1906
Nursery Stock No.
Nursery Number 1905
Mimeo Number
Name
No. Seed Counted Out
No. Hills Planted
No. Plants
% Lodged
Height of Stalk
Height of Ear
No. Plants Harvested
Number Stalks
Ratio
% Marketable Ears
Weight of Ears
Weight of Corn
% Weight in Ear
Weight of Corn
Weight of Cob
Weight of Shelled Corn
% Weight Per Ear
% Cob
% Shrinkage
101 102 110 13 Improved Yellow Dent 200 176 9/8 2 7-4 70 163 11 9/11 62 765 570 .53 751 129 622 .45 823 16.0
201 102 111 " " " " " " 6 7-6 68 162 20 9/11 62 980 725 .67 708 116 592 .41 836 25.5

Chart V.—A page heading and a few notes from the Crop Nursery Year Book.

As the seed from the selected ears is planted in the breeding plot the row from each ear is given a centgener number. These centgener numbers for certain nursery stock numbers will change from year to year, because some of the individuals are constantly dropping out. Therefore a N. S. number may have centgener 701 this year and the following year be planted under centgener No. 101 or 301, as the case may be.

The selected ears are given a plant number (sometimes also called nursery number). This number bears the same digits as the centgener number, except the last two. Thus centgener 12501 has plant numbers 12505-06-07-08-09, etc. With this system the chances for error are very slight and the tracing of pedigrees is made easy. The plant number gives the key to the centgener which in turn gives a key to all plants selected from it.

CENTGENER NOTES—CENTGENER SELECTION.

In all lines of breeding the more data or notes taken the better, so long as they have some bearing upon intrinsic qualities. It would be possible, of course, to take too much data, but usually this mistake is not made. As far as possible, all notes, where judgment is expressed, should be taken in percentages or with 100 considered

as perfect. In this way the comparison of centgeners is made possible. On the other hand, such notes as "good, very good, excellent, poor, very poor, fair, etc., etc.," are not comparable because there are degrees of a character not expressed as *c. g.*, between good and very good or good and fair. With the percentage plan the breeder may differentiate to as small a degree as he desires.

Presupposing that, the time of planting the culture, the time of harvesting, the time of husking, the care of the crop, etc., are exactly the same (as they should be) for all centgeners, the most important notes to be recorded upon the centgeners are as follows:

Date of maturity.
Number of plants harvested.
Weight (gross) of centgener.
" (net) of shelled corn.
" (net) of cob.
Average weight per plant shelled corn.
Average per cent of shelled corn to ear.

Such notes as these are of inestimable value in selecting the centgeners from which to select ears for the next season's planting. They form the basis which indicates to the breeder the efficiency of the mother plant. There are, however, other notes which greatly assist one in selecting centgeners, which according to the above notes, are apparently equal. Such notes as the following are in this latter list:

Height of stalk.
Height of ear .
Length of shank .
Leafiness.
Resistance to lodging.
% of smut.
Time of tasseling.
% of stooling or suckers.

Such notes while not an absolute necessity are considered valuable. They provide a check upon the others and help one to avoid diseases or undesirable features of growth which might creep in if unguarded. They are, as a rule, closely correlated with the yield and maturity and are, therefore, necessary to the best of success.

Fig. 31.—The method of storing the centgener corn and selected ears previous to getting the dry weights. The bulk corn is shown on the right hand and the selected ears on the left. In cloudy, damp weather, it is some times found necessary to force air, circulation to prevent molding. The electric fan used for this purpose at University Farm is shown. When ample windows and a stove are available such a device is unnecessary.

A common fault among breeders is the fear of discarding a great many stocks that they think might possibly prove valuable. In other words, they hold more stocks in the breeding plot than are really necessary. A good breeder must be fearless and perhaps unknowingly discard a few good individuals with the multitude of poor ones. One must learn to rely upon the data accumulated and not give way to the possibility. Save only those which show by their "performance record" that there is profit in continuing them. Most emphasis should be placed upon average yield per plant and early maturity. The average per cent of shelled grain to the ear is important, but should not precede yield or earliness in the choosing of centgeners or plants.

The method of selection followed by the writer for the past five years is as follows: At husking time the cent-

geners are inspected and those showing marked weakness or low yield are immediately discarded. From the remainder the best five to ten ears are picked out and saved separately.

The rest of the ears are sacked in gunny sacks to await the recording of notes on the field-cured product as follows:

Gross weight of ears.
Gross weight of stover.
% of marketable ears.
Average weight of ears per plant.
Average weight of stover per plant.

TABLE XXXV.—Averages of all centgeners by years 1902-1906.

Year	Minn. No.	% stools	Total number plants	Weight of stover	Weight of corn	Av. wt. grain per plant	Dry wt. of corn	Weight of cob	Net weight of shelled corn	Ave. wt. per plant	% corn to ear	% shrinkage
	GREEN WEIGHT						DRY WEIGHT					
1902	172	29.6	129.7	78.8	79.5	.62						
1902	13	38.8	80.6	56.6	56.1	.69						
1903	172		144.6	173.2	110.8	.77	NOTE.—Dry weight notes were not taken, except on selected centgeners.					
1903	13		156.8	177.0	107.5	.67						
1904	13	6.8	136.4	56.0	61.8	.45						
1905	13		146.7	65.2	78.8	Lost						
1906	13	27.4	161.2	87.2	95.7	.59						
Average	13	25.6	159.3	115.7	98 4	.63						
1904	161	48.8	156.0	83.7	82.5	.51						
1905	161		162.3	97.0	86.9	.54						
1906	161	28.0	155.5	78.7	90.2	.58						
Average	161	38.4	157.9	86.5	86.5	.54						

NOTE.—In making up this table the average of *all centgeners* of each year were made. The Minn. No. 172 in the Minn. No. column is merely a selection of No. 13 but numbered (172) in order to designate the selection. In 1904 the best of each stock were united. See chart VIII, page 234 for key.

TABLE XXXVI.—Averages of selected centgeners of corn.

Year	Minn. No.	% earliness in tasseling	% stools	No. of early plants	No. of hale plants	Total No. plants	Weight of early plants	Weight of late plants	Total weight of plants	Weight of stover	Weight of corn	Av. weight of grain per plant	% marketable ears	Total dry wt. of corn	Weight of cob	Net wt. of shelled corn	Ave. wt. per plant	% corn to ear	% shrinkage
								GREEN WEIGHT						DRY WEIGHTS					
							Lbs.	Lbs.		Lbs.	Lbs.	Lbs.	Per Ct.	Lbs.	Lbs.	Lbs.	Lbs.		
1902	172.		42.0			124.0				84.5	86.0	.70		70.0			.57		
1902	13		32.0			82.6				62.0	62.0	.750		46.3			.59		
1903	13		19.3			147.9				187.0	116.8	.790		90.3			.61		22.7
1904	13		14.5			138.7				59.3	67.2	.49		43.0	7.8	35.2	.25	80.0	36.0
1905	13	73	30.0	61.0	92.0	153.0	33.7	53.6		69.0	87.3	.570	45.0	72.8	11.4	61.2	.47	84.4	16.6
1906	13		29.0			162.0				87.4	96.7	.60	73.4	74.0	11.8	62.1	.46	84.1	23.8
Average	13		27.8			134.7				91.5	86.0	.65		66.1			.49		
1904	161		51.4			159.0				89.1	79.5	.540							
1905	161	78	52.0	67.0	96.0	163.0	38.9	51.0		97.5	89.9	.550	49.4	74.4	11.4	62.9	.46	84.7	16.7
1906	161		37.0			144.0				87.4	89.8	.62	82.9	72.8	11.7	61.1	.51	83.8	18.9
Average	161		48.8			155.3				91.3	88.4	.57							

NOTE.—In this table the *selected centgeners only*, are averaged. In comparing these data with those in Table XXXV, page 221, the green weights here given must be used since only the green weights appear in Table XXXV.

For the purpose of getting these weights, platform scales are taken to the field and especially equipped. In fig. 26, page 214, these are shown.

The sacks are then taken to the seed rooms and the ears spread out (and kept separate) to cure. About the month of January the so-called "dry weights" notes are taken. These are the same notes as mentioned under field-cured products. When these notes have been properly compiled, the best ten to fifteen centgeners are picked out. From these the five to ten best ears, as selected in the field, are subjected to a series of tests for final selection.

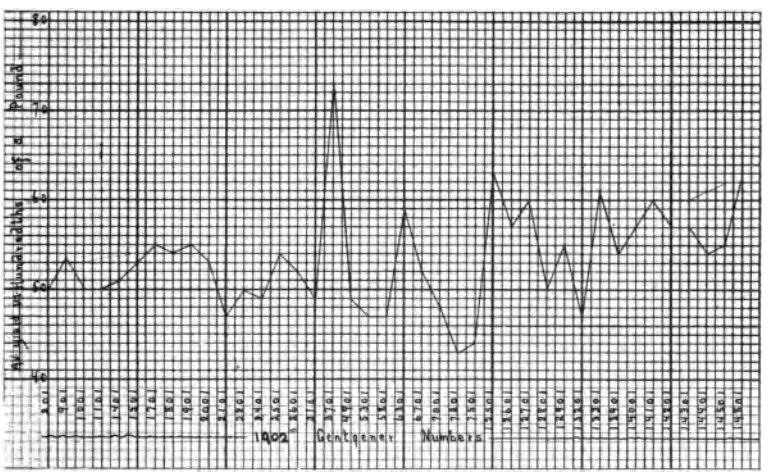


Chart VI.—A graphical expression of the average yield per plant of 1902 centgeners of corn. It will be noticed that the yields run up and down apparently without the difference in soil conditions. Duplicate tests of the same centgeners are very similar, tho planted in another part of the plot. Such a chart is often an aid in selecting the best centgeners.

EAR NOTES—EAR SELECTION.

When the selection of centgeners has been made, the separately saved ears from these cengeners are given plant numbers. These plant numbers are arranged within the scope of the centenger number. Thus centgener No. 201 may have five selected ears which now must be given plant numbers. It might cause slight confusion to start the first one with plant number 201. Therefore, to avoid this, the plant numbers are usually

started (arbitrarily) at No. 205 and run consecutively 206, 207, 208, etc., or 605, 606, as the case may be. In this way each 100 plants of the centgener could be given a number. It is seldom, however, except in foundation beds, that the full century is registered in this way. As the ears are numbered in this way, they are placed in envelopes upon which are recorded the class and stock and plant number. Thus I-'98-St. Paul, Minn. No. 13 plant No. 206 or whatever number it may be. In this way all mistakes or unnecessary confusion are avoided.

The ears, each in turn, are submitted to a rigid score card test. In this test the same person or persons do the entire lot. This seems a necessity to obviate the difference of a personal equation or point of view. On page 225 will be seen the score card as used and some of the scores of selected ears.

After the scores are all made the ears are weighed. The number of rows of kernels are counted and the length and circumference are measured. The ears are then shelled and the weight of the shelled corn and cob obtained. The shelled corn is put back into the envelope from which the ear was taken. The per cent of shelled corn to the gross weight of the ear is determined (by dividing the weight of shelled corn by the gross weight of the ear) and recorded. This completes the notes or data. They are now arranged in tabular form for the breeder's scrutiny in selecting for the best.

It will be remembered that 25 or more centgeners, with which to work, were advised. For practical purposes about 50 has been found to be satisfactory in every way at University Farm. This number varies more or less each year according to the relative comparisons of the ears from which selection is made.

In this method of selection it is obvious that some excellent appearing ears may be discarded. In this work it is not (as has been stated) the individual, for the individual's sake, that the selection is made. It is the individual which shows, by the performance of its progeny, that there is a blood line, inheritance, breeding, or whatever it may be called, behind it. Therefore the notes should be thoroughly reliable and when taken, be the

TABLE XXXVII.—Averages of selected ears of corn.

Year	Minnesota number	Market condition	Form of ear	Circumference	Length	Variety characters	Tips	Butts	Kernel uniformity	Shape of kernel	Color of grain	Color of cob	Space	Space between Kernels at cob	Average score	Gross wt. of ear	Weight of cob	Net weight of grain	% grain to ear
																grams	grams	grams	
1902	172	79.8	70.6	94.7	87.4	69.4	58.7	67.7	71.1	75.9	77.2	83.7	78.7		76.4	235.3	38.9	196.4	82.3
1902	13	75.0	76.0	97.2	91.4	68.0	68.0	68.0	71.0	75.4	74.3	77.0	63.0		76.0	265.5	43.3	222.2	83.3
1903	13	81.0	81.0	86.0	82.0	75.0	76.0	76.0	70.0	78.0	87.0	86.0	84.0		74.2	247.9	44.1	204.0	82.0
1904	13														76.3	185.2	33.0	152.1	81.4
1905	13	82.0	80.0	96.0	98.0	77.0	68 0	74.0	72.0	64.0	88.0	84.0	80.0		81.9	273.2	42.3	230.1	84.3
1906	13	69.0	80.7	92.0	92.0	76 0	27.0	62.0	72.0	74.0	86.0	94.0	69.2		74.7	272.6	40.9	231.8	85.0
Grand Average		77.4	77.7	93.2	90.2	73.1	59.5	69.5	71.2	73.5	82.5	84.9	75.0		76.6	246.6	40.4	206.1	83.1
1903	161	56.2	60.0	77.4	80.6	66.6	67.3	68.3	69.4	72.4	78.8	76.0	63.8		70.9	188.1	38.7	149.4	79.5
1904	161															213.8	36.7	177.1	82.8
1905	161	81.0	75.0	96.0	98.0	66.0	63.0	67.0	70.0	56.0	82.0	82.0	78.0		77.9	274.1	42.9	231.2	84.2
1906	161	55.0	93.0	92.0	92.0	53.0	42.0	53.0	58.0	54.0	77.0	98.0	26.7	35.0	62.3	267.8	42.2	225.4	84.0
Grand Average		64.1	76.0	88.5	90.2	61.9	57.4	62.8	65.8	60.8	79.3	85.3	56.2		70.4	236.0	40.1	195.8	82.6

NOTE.—In this table the averages are made of the selected ears only, or those which were picked to continue the centgener row test. All score card points are represented with 100 as perfect.

TABLE XXXVIII.—Averages of Field-Selected Ears from Selected Centgeners of Two Varieties.

YEAR	Minn No.	Score Card Average	Gross weight of ear	Weight of cob	Net weight of grain	% grain to ear
1902	172	77.0	227.9	38.5	189.4	82.2
1902	13	76.0	258.0	42.1	215.9	83.7
1903	13	70.0	235.2	44.2	190 7	81.8
1904	13	74.9	182.0	32.7	149.3	81.0
1905	13	81.6	247.9	39.0	208.9	84.2
1906	13	69.1	238.3	36.9	201.4	84.6
Total Average	13	74.8	231.6	38.9	192.6	82.9
1903	161	68.4	180.2	37.1	143.1	79.4
1904	161		208.4	36.4	172.1	82.2
1905	161	77.8	247.3	38.5	208.5	84.4
1906	161	62.3	247.5	40.8	206.7	84.6
Total Acreage	161	69.5	220.9	38.2	182.6	82.7

NOTE.—These averages are of all the ears selected in the field from those centgeners which were afterward selected. Note the No. 172 is merely a separate selection of the same variety (No. 13), afterward united with the No. 13—1903 stocks. Comparing these figures with those in Table XXXVI, in which the selected centgeners are tabulated, it will be noticed that in all cases the figures for the selected ears do not exceed those of this table. This comes largely from the fact that nothing was sacrificed for yield. Thus the score card notes and per cent of grain to ear do not always appear in the relation we would naturally expect them to.

"cold blooded" basis for final selection of those that survive and those that are discontinued.

In selecting the ears, as in selecting the centgeners, the chief points for consideration are net yield of grain per plant (ear). Other notes, especially the score card notes, are accessory to these. They are, however, of considerable aid and should always be recorded.

SELECTING KERNELS FOR PLANTING.

Numerous tests have shown that "in the long run" there is a marked difference in favor of the middle and well formed kernels over those from the ends of the ears. In a carefully conducted test of vitality, the middle kernels were 10% better than those from the butt of the ear and 30% better than those from the tip of the ear. With this point in mind the shelled corn from the selected ears is dumped on a table and sorted. From 100 to 250 of the very best shaped and otherwise perfect kernels are counted out for planting the breeding plot the coming season.

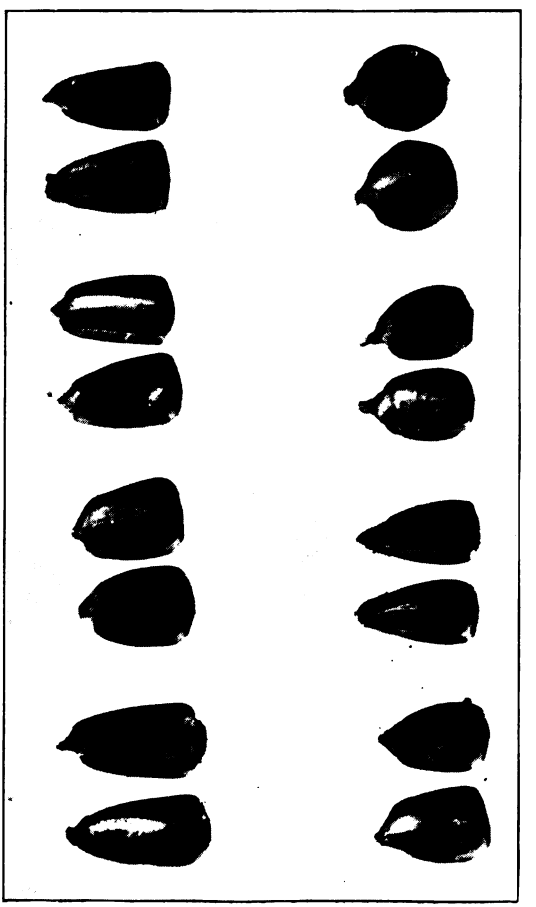


Fig. 32.—Some good and some poor kernels of corn. The form of kernels grows poorer from the upper left hand pair down to the lower right hand pair.

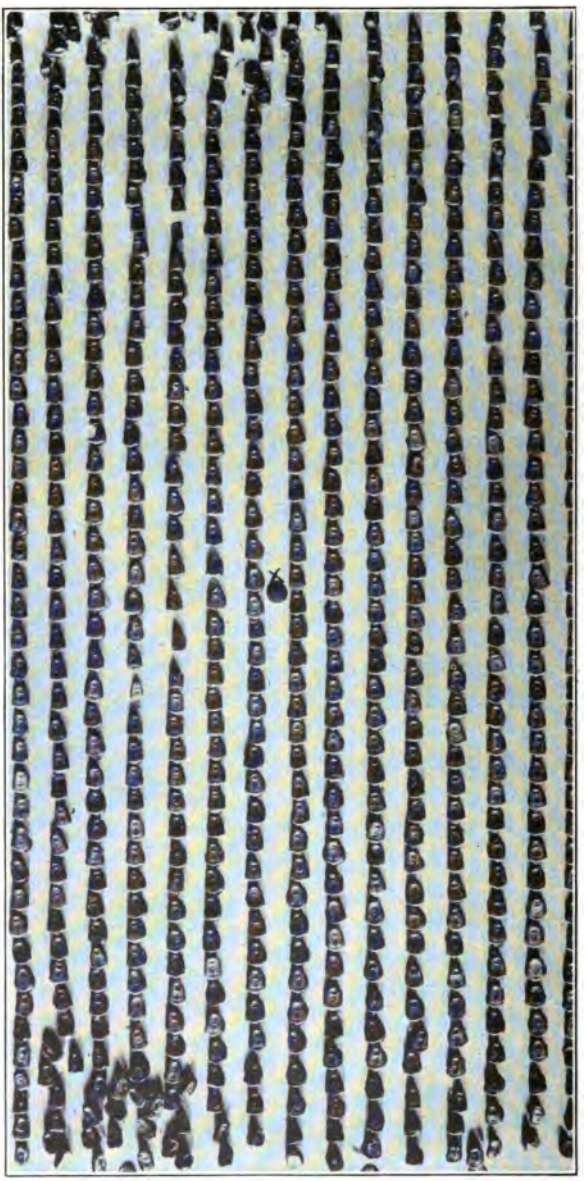


Fig. 33.—The plot of an excellent ear of Minnesota No. 13 corn. The kernels in each row are laid just as they appeared on the cob. All irregularities are in this way apparent. Note the straight, regular (only slight variations) uniform rows and the general quality of the kernels. The tip (top) and butt of this ear were very nearly perfect. X in the center is a thumb tack, not a kernel.

Fig. 34.—Shelling the commercial seed. Note that the tips and butts have been shelled separately and, therefore, do not get into the seed intended for sale.

These select kernels are placed in a planting envelope and sealed. Upon the face of this envelope is recorded data that will serve as a classification and a guide in planting.

THE PEDIGREE.

To apply the word pedigreed to a variety of corn would at first thought be looked upon with suspicion. A pedigree is merely a record of ancestry and why should not a record of ancestry be possible in corn or any other plant as it is in live stock? Ancestry is in this case taken to mean the immediate parents, grandparents, great-grandparents, and so on as far back as is possible to run the lineage. The feats or accomplishments of the ancestry determines the value of the pedigree. Breeders of live stock do not get pedigrees by letting the males and females run indiscriminately together. They single out the var-

ious representatives of each sex and breed them, keeping a careful record the while of the accomplishments of both parents. It is just as possible to single out the individuals in corn and keep their record as it is to do so with animals, but in considering a pedigree of plants, it must be borne in mind that in most cases a plant is both male and female (Hermaphrodite) and in open fertilized plants, as corn, it is impossible to single out the individual plant as the male parent. In fact, the pollen (male element) is furnished by a number of individuals. It is, then, impossible to get an exact pedigree except by hand pollination. A man has no means of knowing what one plant furnished pollen for a certain ear, and it is unreasonable to suppose that it was furnished by one plant, as pollen is scattered promiscuously by the wind. There is no assortative mating in nature. Mating with a species is all a matter of chance, especially in plants, unless controlled by man. Even two species within a genus will sometimes "chance mate" in the absence of the other sex of their kind. The so-called "sport" is probably in some cases formed in this way. Sports, however, are a good thing to avoid, except in an experimental way.

Pedigrees in plants are for the most part a record of that plant which bears the seed or fruit selected. The male parent is practically an unknown factor except that its parent may have been known and tested. For instance, if we have two centgeners of corn A and B, side by side, and by some means force the pollen from B to fertilize the ears on A and select 10 ears from A, we have a pedigree of those ears except that there is no way of knowing what plants in B furnished the pollen. What we really have is a complete record of A and B; a record of each plant in A or B if we choose. We know the record of the selected dams, but the actual sires are unidentified except that they must be of the "blood" B.

If, on the other hand, we force (by hand pollination) plant No. 20 in B to pollinate plant No. 75 in A and then test both No. 20 and No. 75 we have a complete pedigree and a record of each.

In breeding by selection the best centgeners are planted in an isolated plot. The records of the dams are known and the lineage from this parent complete. The

lineage on the other side, however, consists of records of grandparents, which are the dams of the real parents. If a record of the sire were necessary, an average of all other centgeners would give as near a correct figure as would be practical to obtain. The pedigree shown on page 234 and the table on page 225 furnish the data.

In the foregoing pages there is outlined a method of breeding, which, if followed, will give a record of ancestry, or a pedigree. The record and source by years of the centgeners in the 1907 breeding plot give an accurate pedigree of each one and plainly point out the value of keeping such records.

Sooner or later the raisers of seed grains will find it necessary to breed their varieties with as much care and precision as the live stock breeders today do. Much progress may be obtained by seed selection, either with the faniing mill or by hand-picked stocks. This is not breeding, however, for the basis of selection rests on the size and weight of the seed and not upon inheritance of superior quality. Selecting "seed-ears" of corn from the field at husking time will greatly improve the crop, but it does not give proper advantage to those few individuals possessed of a strong inherited ability.

The starting of a breeding plot is nearly always a difficult question for the average farmer. The writer is not prepared to say that in all cases it is advisable. Under most conditions it will pay even for the improvement to be experienced upon the home farm. In some cases it will become highly remunerative. Where a farmer has a quarter section or more of land he can well afford to breed his own corn and save seed for his less thrifty neighbors. There are always those who buy seed corn and they must be supplied by someone.

To illustrate the method by which the breeding plot works its improvement into the field, the registry chart is given (see page 232).

It will be seen by the chart that the 1907 selected ears from the foundation stock (F. S.) are planted in 1908 in a breeding plot or Centgener Row Test (C. R. T.). In 1909 the C. R. T. comes from the best ears saved from the selected centgeners from the C. R. T. of 1908. In this manner each year a C. R. T. plot is grown. From

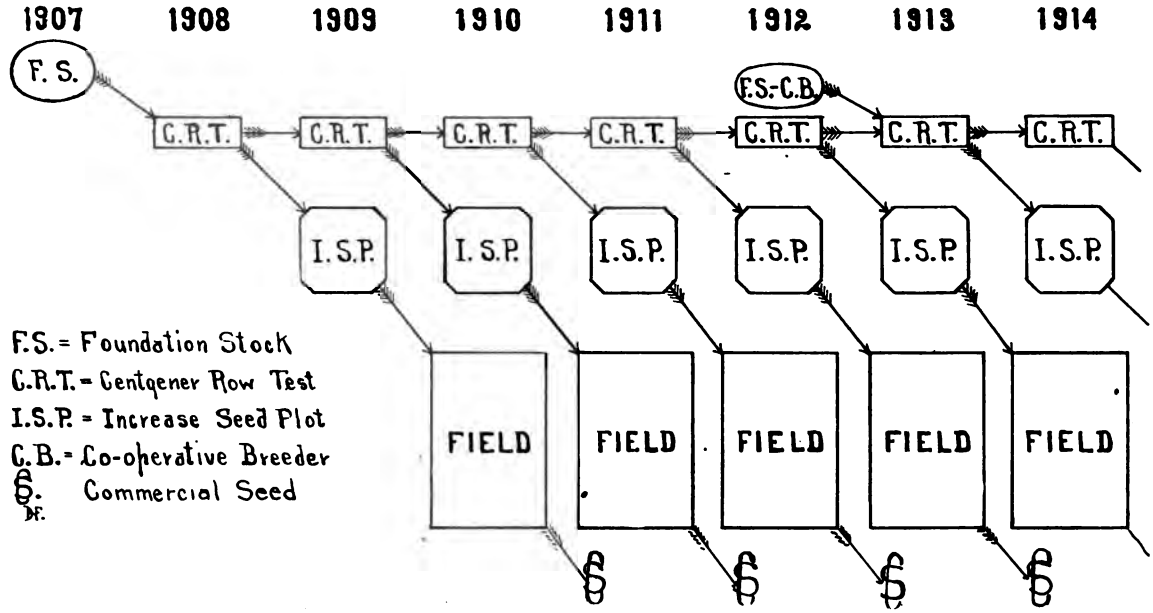


Chart VII.—Plan for corn breeding, showing the method of carrying on a breeding plot and at the same time making the undertaking doubly profitable. It will be noticed that in three years from starting the foundation stock (F S.), seed corn may be sold The (F. S.) indicates, the ears selected from the 1906 crop. The (C. R. T.) indicates the centgener row test which is made each year. The (I. P.) designates the increase plot planted from the best bulk seed from the (C. R. T) after the mother ears have been selected. The field is planted from the best grade of seed from the (I. P.) and furnishes the corn for feed, also the marketable ears designated as commercial seed. In case the field does not require many bushels of seed the increase plot may not be necessary as the (C R. T) will furnish enough. In 1912 another foundation plot is started. In 1913 the selected ears from it are crossed with those of the (C. R. T.) This F. S —C. B.) may be obtained from a co-operative breeder.

the remaining good ears of the C. R. T. plot an Increase Seed Plot (I. S. P.) is annually planted. From this I. S. P. the best ears and seed are saved to plant the field. From the field the best seed may be saved for sale at a good average price. As shown by the table it will take three years before field results are experienced. They will continue annually thereafter.

As corn is inclind to deteriorate rapidly or "run out" if in-bred, it will be preferable to introduce some new "blood" in about five years. If co-operative breeding can be secured better results would come from introducing this new blood from another breeder. In lieu of this an infusion can be had by selecting from the field or especially prepared foundation plot a new foundation stock (F. S.) as indicated in 1912. In 1913 alternate rows from (F. S.)-C. B.) and (C. R. T.) ears selected from best centgeners will be planted in C. R. T. plot. Those centgeners coming from the C. R. T. will be detasseled, thereby insuring cross fertilization. The ears for the 1913 C. R. T. plot will be selected from the detasseled rows. A few years more of breeding and (about 1917) another infusion of outside blood should be made.

The records of such a method of breeding will prove of very great interest and furnish a most valuable pedigree. Minnesota No. 13 corn has been bred with good results for the past five years, according to this method.

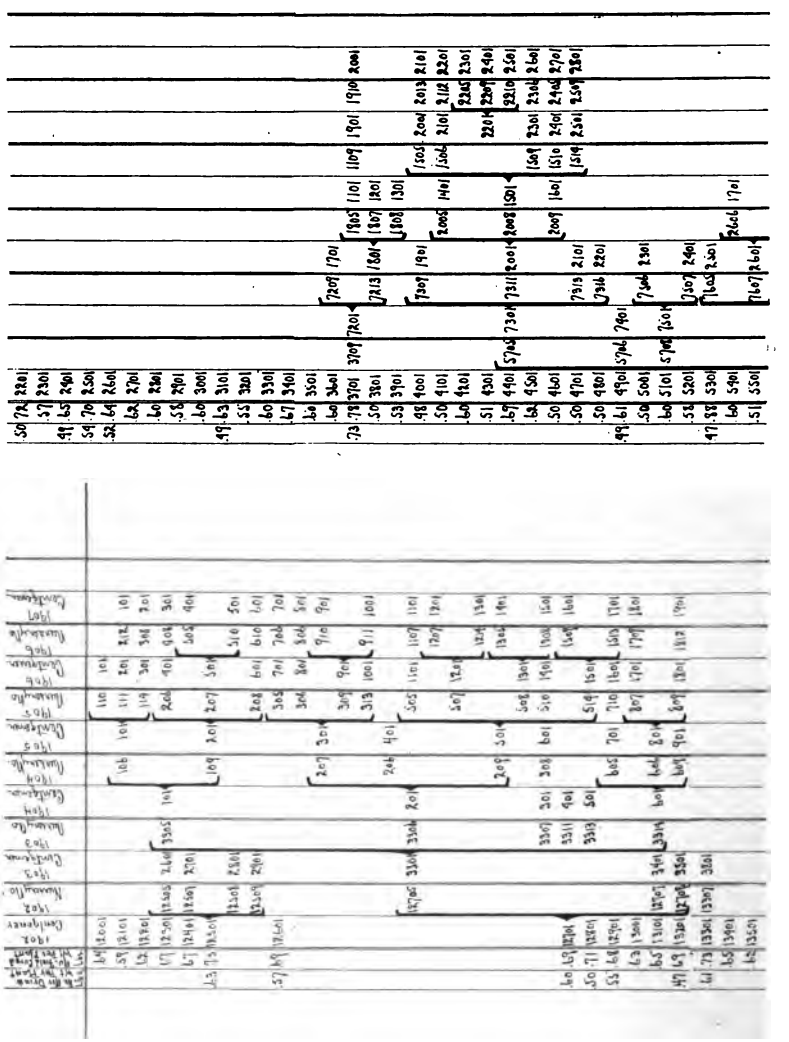
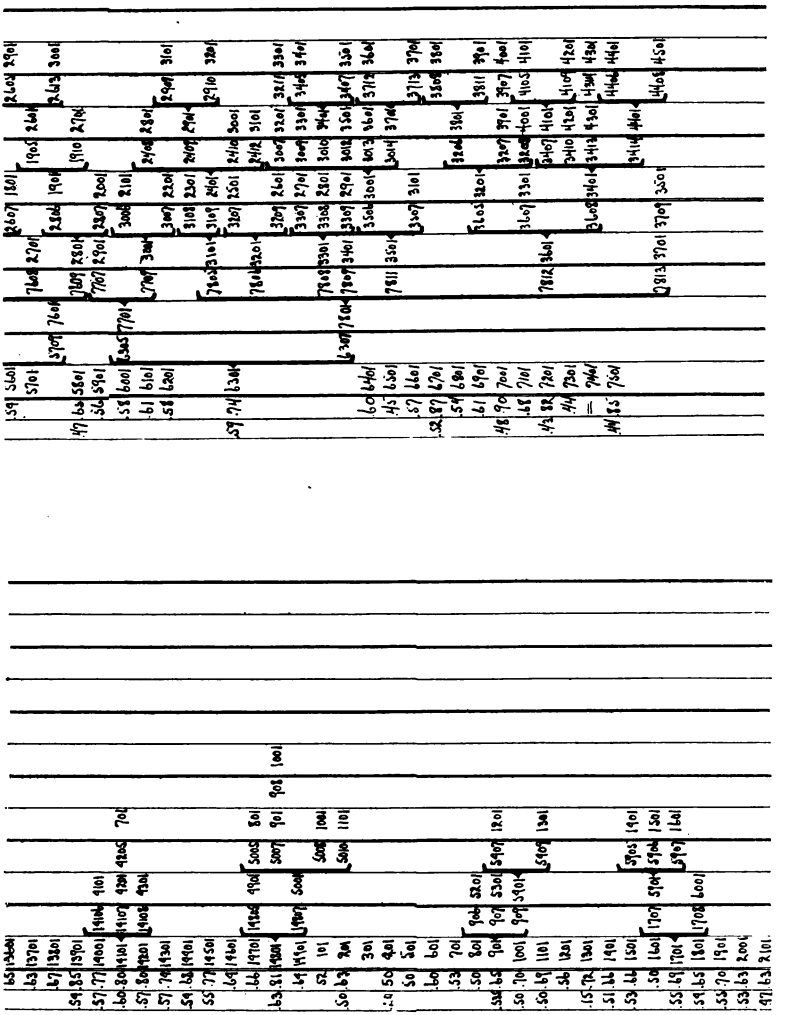


Chart VIII.—The pedigrees of the 1907 centgeners of Minn. No. 13, corn tracing back to the foundation ears selected and given centgener test in 1902. In the first and second columns on the left are given the field weights of all centgeners and the dry weights of the selected centgeners of 1902. Those centgeners which were finally selected, from which ears were saved to plant the 1903 centgeners, are indicated by the brackets arising from them. The number of ears selected to plant centgeners the next year is indicated by those numbers embraced by the respective brackets, e. g.



centgeners 12501 in 1902 had four ears selected, 12505-'07-'08 and '09. In tracing the pedigrees bear in mind that the columns bearing the same year number (1902, etc.) represent the centgeners of that year together with the ears saved from the selected centgeners. Also bear in mind that the selected ears become the mothers of the centgeners of the next year, which are shown in the succeeding column.

To follow the centgeners thru, the records run from the bottom of page 234 to the bottom of page 235, then to the top of page 234 and from there to the top of page 235.

PEDIGREE CHART.

The pedigree chart here shown illustrates exactly what has taken place at University Farm in breeding Minnesota No. 13 corn to the degree of quality that it now possesses. In 1902 there were 105 ears tested in centgener rows. The field cured weights are all shown, but the air dry weights are not all shown because some of the centgeners were discarded "at sight" when the husking was done and the first weights taken. Of those saved some very high yielders, it will appear, were not selected according to field cured weights. This is explained by the fact that the weight results partly from immaturity and hence much moisture in the ear. The air dry weights of these fall below those finally selected for the next year's planting. Examples of these are centgeners 5301, 6701, 7001, and 7201.

From ten selected centengers 25 ears were saved and planted in 1903. These were selected as in 1902. Eleven centgeners were continued and 37 ears selected for planting in 1904. From the 1904 centgeners eleven were selected and from these 35 ears were chosen for 1905 centgener plot, and these become centgeners in 1906. Thirteen of the 1906 centengers were selected and from these 45 ears were selected to plant the 1907 centgeners.

It will be noticed that of the one or more ears saved (from each of the selected centgeners) and planted in centgeners the following year, the most of these ears are discarded. Thus from year to year the original selected stocks "fall by the wayside." By tracing the pedigree of the 1907 centgener back we are surprised, yet gratified, to find that our expectations were realized, viz., that only a few (4) of the original are still in the field. These are numbers 12701, 3701, 5701, and 6301. The other centgeners originally selected were discontinued as follows:

12501 in 1903.
13301 in 1903.
14101 in 1904.
901 in 1904.
1701 in 1904.
14901 in 1905.

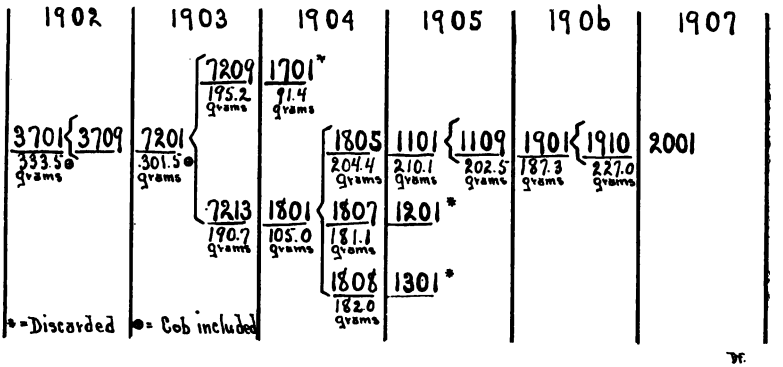


Chart IX. A chart showing the pedigree and record of centgener 2001 in 1907. The centgener and plant numbers are given above the lines. The average yield per plant in the centgeners and the yield of the plant in grains are given below the lines. The yield of Plant No. 3709 in 1902 was lost.

THE SCORE CARD.

The score card as an aid to the corn breeder has been briefly mentioned in the foregoing pages. As an aid to farmers in recognizing and studying his breeding stock it has a greater value and is, therefore, worthy of further discussion. Some critics have referred to the score card as being useful only in fixing so-called fancy points upon a variety and having no practical utility. This is hardly the case, however, with corn score cards. Every point upon the Minnesota Score Card has, directly or indirectly, a utility value. Pretty ears of corn sometimes score high, but it is not the purpose of the score card to emphasize beauty. On the contrary, usefulness as indicated by yield and quality, is the aim. It has been commonly observed, however, that the pretty ears are generally useful ears, especially if the variety which it represents is standard. Uniform, even, well filled ears have regularly formed, well developed kernels, which usually go hand in hand with yield and quality. The only true way to judge an ear of corn is by its progeny, and it is in this way that the score card has been established. It will, as sometimes it does with live stock, mislead in judging real worth, but the fact remains that it is a material aid in picking out ears for planting.

SCORE CARD FOR SEED CORN EARS.

Minnesota Judging School,

Division of Agriculture. St. Anthony Park, Minn.

POINTS NOTED	Standard Score	Sample No. Score	Sample No. Score	Sample No. Score	Sample No. Score	Sample No. Score
1. Market Condition	10					
2. Form of Ear	15					
3. Size of Ear	5					
4. Uniformity and Variety Characters	10					
5. Tips of Ears	10					
6. Butts of Ears	10					
7. Kernel Uniformity	5					
" Shape	5					
8. Color Grain	10					
" Cob	5					
9. Space between Rows	3					
Space Between Kernels at Cob	2					
10. Per cent Grain to Ear	10					
Total Points	100					

Chart X. The score card in use up to 1907. A new one which goes greater into detail is now in use in the Judging School.

Score cards for the different corn growing states will necessarily differ. The Minnesota score card is divided into ten heads. Each head bears upon a point of economic value. These may be grouped under three major subjects for further consideration, viz., Breed characters, vitality and yield.

Breed characters as represented by (2) Form of ear, (3) Size of ear, (4) Uniformity and variety characters, (7) Kernel uniformity and shape and (8) Color of grain and cob, indicate the purity of the variety of corn and change with the breeds. The total of these points is 55% of all. It is believed that the amount is justified upon the basis of breeding. For example, individuals in live stock are inspected closely for breed or type characters, because it is recognized that if they carry these points well they have the breeding behind them. In addition to this the form of an ear of corn and the shape of its kernels are influencing factors of yield. It is true that certain "ones" in live stock or in a corn field, are better than the average of pure bred lines. It is also true that a first cross often exceeds the pure bred parents, but it does not follow that because this is true, a continued crossing will result in continual improvement. Indeed the contrary will result. In other words, an ear of corn of mixed breeding may be of excellent quality in every way, but if planted there is no

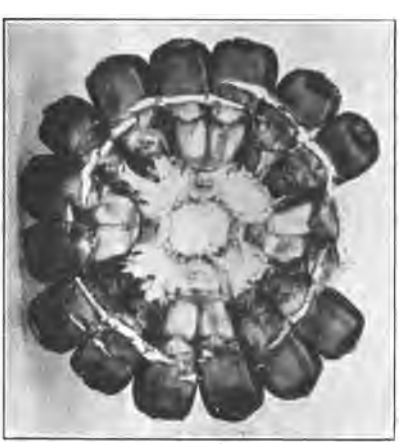


Fig. 35.—A common occurrence—cracked kernels—such seed will not grow. A complete inspection of the ears is necessary to detect such a fault.

assurance that it will reproduce its quality. A pure bred ear will reproduce its quality if grown under normal conditions.

Vitality means life and in the score card is represented by (1) market conditions and incidentally by (8) color. A student of corn will very soon learn to distinguish by color alone what the vitality of an ear may be. It is necessary above all other considerations that the kernels of an ear have life. Second to this it is desired that they be vigorous, healthy and strong. The only true way to test seed for these points is by a germination test, and this test should be made of each ear. By taking ten kernels from as many parts of the ear and germinating them the life and strength or all that vitality implies will be demon-

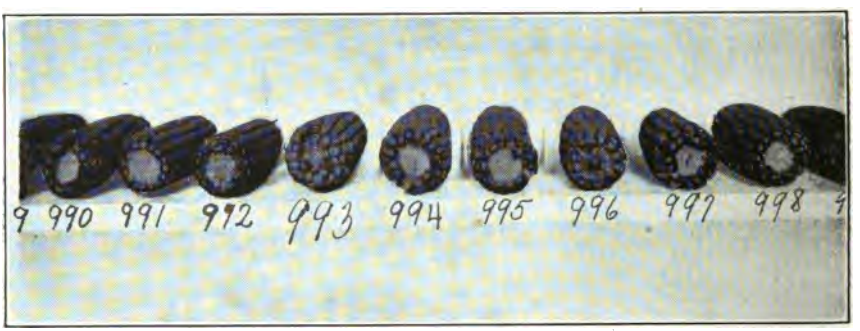


Fig. 36.—Seed ears laid on a board and numbered to correspond with numbers in a germination test box.

strated.

It is important at this point to note that invariably the experience at University Farm has shown that the well bred corn has shown better vitality than any common stock.

To make a germination test of each ear one has but to number the ears and keep track of the kernels from the ears by these numbers.

The most convenient way to do this is (1) to get or make a box about 2 feet wide, 4 inches deep and as long as can be conveniently handled, probably 3 feet. (2) In this, place 3 inches of wet sawdust, bran, sand or anything that will hold moisture. (3) On this, place a muslin or

cotton cloth that has been cut to the exact size of the box and marked off into 2 inch squares which are numbered 1, 2, 3, 4, etc. (4) On these squares place the ten kernels from the ears which bear the corresponding numbers. (5) When all kernels are thus arranged, place another cloth over all and sprinkle a half inch of wet material on top. (6) Set the box where the temperature will remain above 60 degrees F.

In a few days the count can begin. Any square in which at least nine kernels are not growing shows that the corresponding ear is weak in vitality. Such ears should not be used for seed. The length and general appearance of the "sprout" and roots will give a fair idea of the health and strength of the seed.

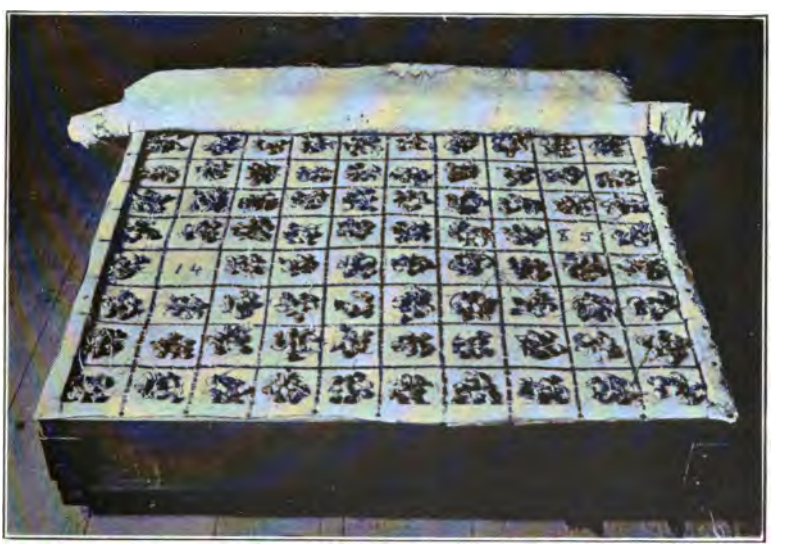


Fig. 37.—A germinating box with kernels from separate ears on the squares. The kernels on squares 14 and 85 did not grow. The ears corresponding to these numbers were discarded.

A convenient way of numbering the ears is to place them on a board, table or floor with a nail or block of wood between each two. Numbers can then be made with pencil or chalk at the base of each ear. Another way is to pin small squares of numbered paper on the butts of the ear.

Yield.—The one thing which gives a variety of corn its real value is its ability to yield a large number of bushels of shelled corn per acre. The score card, as bearing upon this point, is carefully arranged and is represented by (2) Form of ear, (3) Size of ear, (5) Tips, (6) Butts, (7) Kernel shape, (9) Space and (10) per cent of corn to ear. Some of these points it will be noted bear also upon breed character. It is hardly necessary to discuss these points further. It goes without saying that the better formed ears, the larger ears, the better filled tips and butts, the better formed kernels, ears with least space between rows and between kernels at the cob and with highest per cent of corn to ear are all points or factors of yield. The degree of perfection with which ears bear these points will indicate their producing power.

SCORE CARD POINTS.

There are a number of varieties of corn in Minnesota. Each variety has certain characters that are different from all other varieties. Such characters make, for the varieties, a so-called "standard of points." These are recognized by the judges and are the basis for the total score given. For most Minnesota varieties these standard points have not been worked out. They have been worked out for Minnesota No. 13 and are as follows:

Length—eight (8) inches.

Circumference—six (6) inches.

Color, grain—rich egg-yellow; cob, deep red.

Kernels—mostly smooth (slightly wrinkeld) cap.
Medium deep dent, same shape as cap.
Cap proportions—1 to 2.
Length and breadth of kernels about 1½x1.

Form of ears—cylindrical, tapering slightly at the tip.

RULES AND EXPLANATIONS OF POINTS.

Each entry or exhibit should consist of ten selected ears.

MARKET CONDITION—10 points.—The ear should be thoroughly mature, dry and sound, and should feel firm when taken in the hand. The kernels must not be injured by mice or worms or by mold; neither should they show any rotten or cracked places. They should have a good, bright appearance, and have a large germ.

RULE.—If the ears have any of these faults they should not be given the full ten points but be scored according to the extent of the defects. For example: If the defects, such as cracked kernels, mould and decay or rottenness amount to about as much as one whole ear and the rest of the corn on the ears is good, the mark should be 9. If it amounts to more than one whole ear and not enough for two ears, mark the exhibit 88½ or 8¾ upon market condition, etc.

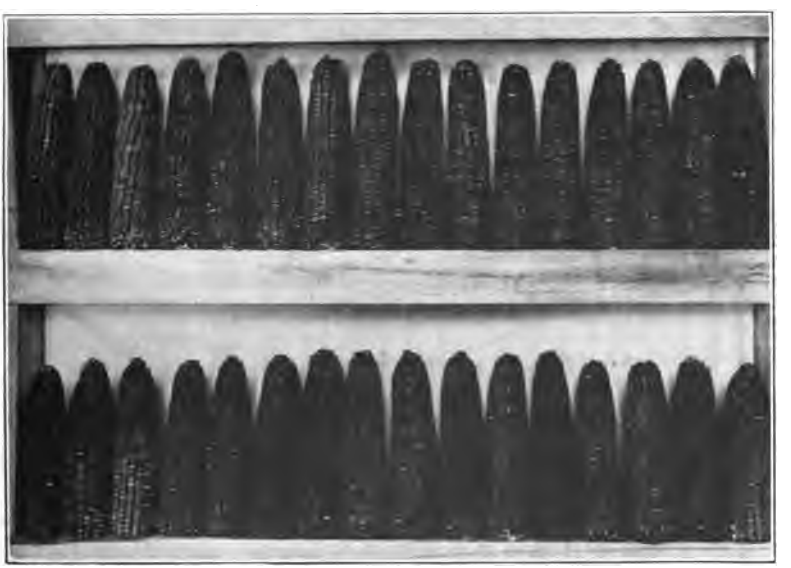


Fig. 38.—Some good ears laid up for curing.

FORM OR SHAPE OF EAR—15 points.—The best formed ears are nearly the same size at the tip as at the butt. The

rows of kernels should run straight from butt to tip. Twisted rows show bad form. The ears can be as long or big around as they can be found but the length and the circumference must be proportional, that is, an ear must not be too big in circumference for its length. The tips and butts of the ears should be blunt and well filled with kernels.

RULE.—There is no definite rule for judging the shape of the ear. Always have a perfect shaped ear in mind and mark the sample according to how near the ten ears come to being perfect. Make due allowance for variety characters.

SIZE OF EAR—5 points.—The size of the ear depends upon the standard for the variety being judged. For example, Minnesota No. 13 should be 8 inches long and 6 inches in circumference.

RULE.—Measure the length of each ear. If an ear is less than standard put down the amount it is less than standard. When all ten ears are measured, add the amounts that are lacking. Then take one point off the standard for each 2 inches thus obtained. For example: The standard is 8 inches.

Ear No. 1 is 7.5 inches long, therefore .5 inch short	.5
Ear No. 2 is 8.5 inches long, therefore nothing short	.0
Ear No. 2 is 8.5 inches long, therefore nothing short	.0
Ear No. 3 is 8 inches long, therefore nothing short	.0
Ear No. 4 is 7 inches long, therefore 1 inch short	1.0
Ear No. 5 is 7.75 inches long, therefore .25 inches short	.25
Ear No. 6 is 8.25 inches long, therefore nothing short	.0
Ear No. 7 is 7.25 inches long, therefore .75 inch short	.75
Ear No. 8 is 7.5 inches long, therefore .5 inch short	.5
Ear No. 9 is 9 inches long, therefore nothing short	.0
Ear No. 10 is 8 inches long, therefore nothing short	.0
Total short	3.0

In the same way the circumference may be measured with a tape line and the shortage figured and cut accordingly. The measurement should be made a little below the middle of the ear. The total score may then be determined.

UNIFORMITY AND VARIETY CHARACTERS.—The color of the grain and of the cob, the shape of the kernels and of the dent in one variety are different from others. There-

fore these are called variety characters. All these should be consistently uniform in all parts of the ear. The ears in the exhibit should be true to the breed represented.

RULE.—Any characters that do not represent the breed must be counted as against the exhibit and something must be counted off for the lack of exact breed characters.

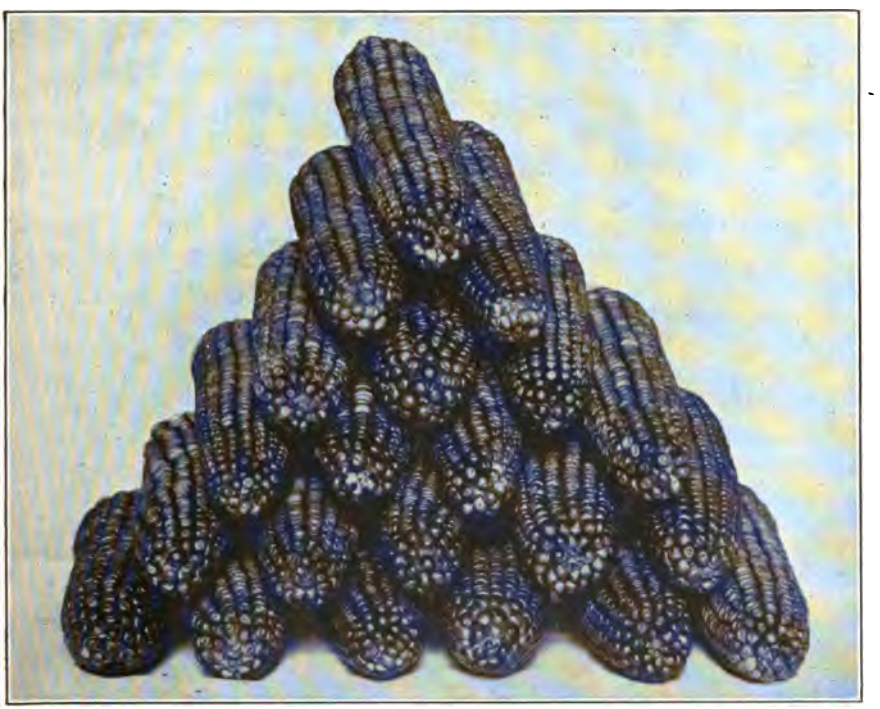


Fig. 39.—The tip ends of some desirable ears showing the type of tips to select for.

TIPS OF EARS.—The tips of the ears must be well filled with kernels and well rounded like a fork handle; not tapering like a horn. The end of the cob must be entirely covered.

RULE.—If the entire end of the cob is exposed, cut

off one full point for each ear thus found. If a little of the cob is seen, or the kernels are not good size and shape, cut off as much as is thought proper.

Fig. 40.—The butt ends of 15 high scoring selected ears. These illustrate the form of butt desired.

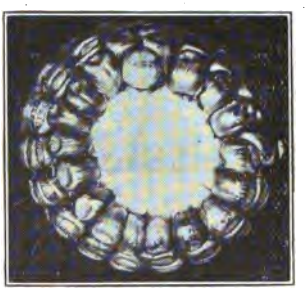


Fig. 41.—A perfect butt of an ear of corn. Sometimes otherwise imperfect ears have good butts. Such ears should be discarded. But other things being equal always select an ear with as good a butt as is possible.

BUTTS OF EARS.—These should be even and smooth. The rows of kernels must extend over the edge of the butt. The hollow, left after breaking off the shank, should

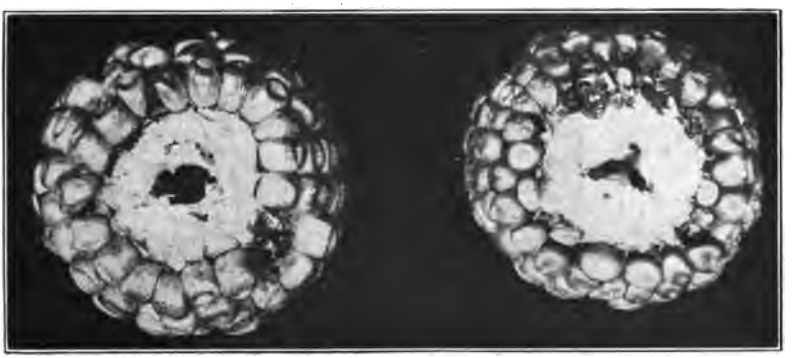


Fig. 42.—The ears having butts of this character should be discarded.

be saucer shaped, and of medium size. The butt must not be large and open nor small and shrunken.

RULE.—According to how much the judge thinks that the butts of the ten lack of being perfectly formed butts, he cuts little or much from the score card.

KERNELS.—Uniformity, 5 points; Shape, 5 points.—All the kernels should be alike in size, color and other characters. The best shape is what is known as the wedge shape, with nearly square corners at the top and sides. This shape fills the cob best and gives the most shelled corn per ear. Round tip kernels or round kernels like those found at the tips of the ears are objectionable. The germ should be large.

RULE.—With the blade of a jack knife pry out two kernels from each ear and lay them in a line, points down in front of the ears from which they were taken. Look them over and push out of line those kernels that are different from the majority. Since there are five points for uniformity, each four kernels make one point. Therefore take off one point for each four kernels that do not remain in the line, or if there are three or four types cut accordingly more.

Do the same way to get the score on shape of kernels Leave only the good, wedge-shaped ones in the line, and mark off one point for each four kernels not left in the line.

COLOR.—Grain, 10 points; Cob, 5 points.—Whatever the color of the variety is, it must be bright and clear.

Fig. 43.—The butts of three ears of corn presenting undesirable features. The left hand one is too irregular and small. The right hand one is too flat and broad. The center one is contracted and runty. It looks more like a tip.

This indicates freshness and good quality. Sometimes a yellow ear of corn will have white or red kernels and white corn will have yellow kernels. Also yellow corn may have a white cob or a white corn a red cob, but this is not a true variety character. They should be of all one color.

RULE.—Cut one point for every four kernels of different color than that of the variety. Cut one-half of all the points if a red cob is found in white corn or a white cob

in yellow corn, unless the cobs are all of the same color and it is common to the variety.

SPACE.—Between rows, 3 points; Between Kernels at Cob, 2 points.—The space between the kernels is caused by the shape of the kernels. When there is a good deal of space the per cent of grain to ear is not as large as it should be.

Fig. 44.—An ear with too much space between the rows. The percentage of corn to ear in such cases is small. Avoid ears having such a pronounced space.

RULE.—Examine each ear and keep in mind the relative amount of space found in each. When all the ears are examined make an estimate of about how much lost space there is altogether, and cut the score accordingly.

PER CENT OF GRAIN TO EAR.—10 points.—The amount of shelled corn is an important point in an ear of corn. In

most varieties of corn there are from 80 to 85 per cent of shelled corn to the ear. That is, in one hundred pounds of corn 80 to 85 per cent is shelled corn and from 20 to 15 per cent is cobs. It is important to have a high percentage of shelled corn, for percentage of corn per ear is a yield factor.

RULE.—Take five of the ears from the exhibit and weigh them carefully on a grocery scale. Then shell them, being careful not to lose any of the kernels. Weight the cobs and subtract this from the weight of the five ears. The difference is the weight of the shelled corn. By

TABLE XXXIX.—Average, Yield and Production of Corn in 1875-1905.

Year	Acreage	Av. Yield per Acre	Production	Year	Acreage	Av. Yield per Acre	Production
1875	251,369	29.2	7,340,000	1899	944,584	33.0	31,171,272
1876	291,338	25.4	7,400,000	1900	963,476	33.0	31,794,708
1877	455,172	29.0	13,200,000	1901	1,361,120	26.3	35,797,456
1878	449,000	38.1	17,106,900	1902	1,483,621	22.8	33,826,559
1879	438,737	33.8	14,831,741	1903	1,439,112	28.3	40,726,870
1880	442,230	35.0	15,478,050	1904	1,554,241	26.9	41,809,033
1881	508,500	32.0	16,252,000	1905	1,507,614	32.5	48,997,455
1882	661,050	32.0	21,127,600	1906	1,492,538	33.6	50,149,277
1883	727,155	20.8	15,124,800				
1884	705,304	33.5	23,630,000				
1885	648,913	28.4	18,431,000				
1886	668,380	29.8	19,905,000				
1887	606,756	29.8	18,081,000				
1888	703,837	29.3	20,622,000				
1889	746,067	28.5	21,263,000				
1890	768,449	27.7	21,286,000				
1891	814,556	26.5	21,586,000				
1892	896,012	27.0	24,192,000				
1893	887,052	28.3	25,103,572				
1894		18.4					
1895	1,152,458	31.2	35,956,690				
1896	1,129,409	30.5	34,446,974				
1897	993,880	26.0	25,840,880				
1898	954,125	32.0	30,532,000				

The average per acre in Minnesota, 1875, 1905 is 29.3 bu.

The average yield per acre in five year periods beginning with 1875:

First	31.1
Second	30.64
Third	29.16
Fourth	25.6
Fifth	30.54
Sixth	27.46
Seventh, (2 yr.)	33.05

dividing the total weight of the shelled corn by the weight of the five ears, the per cent of grain to ear is obtained. For example: The five ears weigh 6¼ pounds, or 100 ounces; the five cobs weigh 1 pound, or 16 ounces; the shelled corn is 5¼ pounds, or 84 ounces. 84 divided by 100 equals per cent of grain to ear.

RULE.—With the standard as 85, cut one point for each per cent less than standard. Thus the above example of 84 per cent would be marked 9 on the score card.

GETTING TOTAL SCORE.—Add the scores of the different characters and the number thus obtained will be the score of the exhibit. Compare the scores of all the samples and those with the highest scores will generally prove to be the best ones for seed.

TABLE XL.—Corn Statistics Compared With Other Grains and Live Stock.

	AREA ACRES	PRODUCTION BUSHELS	VALUE DOLLARS
Wheat	5,119,412	55,801,591	36,271,034
Barley	1,128,265	31,591,420	11,056,997
Oats	2,215,728	72,011,160	19,443,013
Rye	88,448	1,707,046	853,523
Total Grain	8,551,853	161,110,217	67,624,567
Corn	1,492,538	50,149,277	17,050,754
Total Crops	10,044,391	211,259,494	84,675,321
LIVE STOCK		**NUMBER**	**VALUE**
Horses		723,141	70,260,365
Mules		8,657	816,090
Milch Cows		1,019,700	29,571,300
Other Cattle		1,395,000	17,460,900
Sheep		436,593	1,744,626
Swine		1,377,000	12,393,000
Total		4,870,091	132,246,281

RECAPITULATION.

(1)

The early corn crop escapes the frost. Good seed is cheap at any cost. Poor seed is time and money lost.

(2)

Minnesota varieties of corn are not well bred. They offer great opportunities to those willing to start a breeding plot.

(3)

Minnesota varieties lack uniformity of characters. They should be bred to a standard.

(4)

Pollination and the formation of the ear are clearly correlated. Pollination is a matter of chance. The breeder can increase the probabilities of this chance by selecting the most uniform and perfect ears.

(5)

Inheritance, culture, care, soil, water supply and climate, are important factors in corn production.

(6)

The two main laws of breeding are (1) Like begets Like and (2) Variation of characters. These are opposed to each other but without them the breeder would be helpless.

(7)

Breeding by selection and by hybridization followed by selection are two ways of securing desired results. The former is the more practical method for the average farmer.

(8)

The successive steps in the selection method of breeding are the following:

1. Discovering the variety with which to start.

2. Selecting the foundation ears and planting breeding plot.
3. The centgener row test of mother plants (ears).
4. Choosing the best centgeners.
5. Selecting the best ears from the chosen centgeners.
6. Counting out best kernels to plant next year's breeding plot.

(9)

The best variety is one that is sure to mature and will yield heavily.

(10)

The best stalks are thick (not coarse) at the base, strong, leafy and bear a good ear on a short small shank.

(11)

The best ears are cylindrical, large, kernels uniform, rows of kernels straight and yields a high per cent of corn to the ear.

(12)

Weak and barren stalks should be detasseled before the pollen ripens.

(13)

The breeding plot should have uniform soil conditions and the treatment of the plot should be uniform throughout.

(14)

The pedigree is a valuable asset to a variety provided the performance record goes with it. The highest yielding individual is not necessarily the one which possesses the best stamina.

(15)

The score card is invaluable in studying the ear of corn.

(16)

There is room for a corn breeder in every township.

(17)

The experience of a practical breeder is a safe guide.

(18)

Whatever is well worth doing is worth doing well.

Fig. 45.—A montrosity ear, which is often seen but should never appear in a well bred plot or fiedl. This is said to be a reversion to the ancestral type. Plants bearing such ear should be detasseled.

FOURTEEN YEARS' EXPERIENCE

BY

H. P. HANSON, ALBERT LEA, MINNESOTA.

About fourteen years ago we secured from the Minnesota Experiment Station a half bushel of corn called Minn. No. 13. The corn produced a good crop, but the ears were smaller than we had been growing. Our own variety, however, had a large cob and was enlarged at the base of the ears. In these respects Minn. No. 13 was better, and it was also better in proportion of corn to cob. The ears of Minn. No. 13 were often tapering. The kernels were frequently flinty and loose on the cob. There was too much space between the kernels and the type was not uniform. All of these were objectionable so we set about to improve them and adapt the variety to our locality. At first we practiced field selection.

In selecting seed corn we would take only such ears as came nearest our ideal, i. e., mature, good sized ears, with medium deep kernels, straight and even rows, kernels uniform in denting and color. For size and maturity we practiced going through the field early in September or as soon as the husks turn yellow, to pick the seed ears. At this time we can see which ears are early enough and avoid those ears which would be mature at husking time, but not early enough to escape an early frost. We can also take note of the stalk and decide if it is too tall or too short, if it stands well, how the ears are borne. A medium sized stalk with ears placed at the right height for husking is most desirable. We want an ear well filled at both ends, not enlarged at the butt, and tapering but slightly toward the tip; the grain set compactly on the cob, evenly dented and fairly smooth. We avoid chaffy or rough ears, tapering ears and ears with flinty tip kernels.

Part of the time we have been selecting we have detasseled before blossoming all barren stalks and cut away all suckers in the field where we selected our seed. The last three years we have had a breeding plot of about one-half acre in size. This plot is planted in hills three feet six inches each way. Three kernels are planted in each hill. We plant a few rows from selected ears (keeping track of each ear's product) and detassel them to insure

crossing or avoid inbreeding. Barren and weak stalks are also detasseled.

We go through the plots as before explained and select seed ears from the detasseled rows. By weighing or measuring we determine which rows have produced the best. From these rows we save the seed for the breeding plot the next year.

If each hill produces one pound of corn, the rate of yield per acre would be 50 bushels. If two pounds were raised the yield would be 100 bushels.

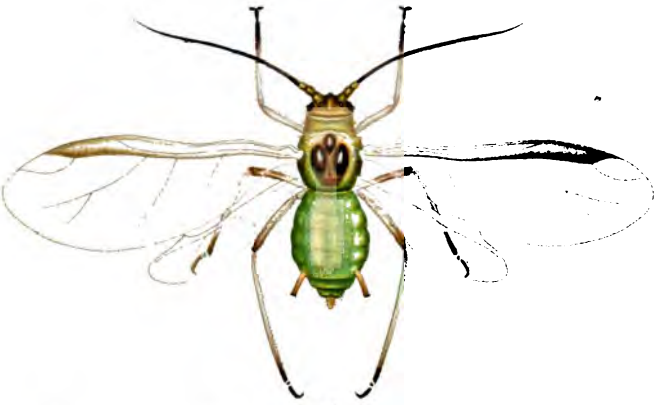
When selecting seed corn early, we leave the husks on and tie the ears together two and two. The ears are then hung in some airy place out of the way of rain and sun. Here it hangs until cold weather and freezing commences. It is then taken to the room above our kitchen, when it is either hung up or placed thinly upon slats about six inches from the floor. In this room we have an extra stove pipe running nearly to the floor. The air gathering dampness from the corn, passes up through this; thus creating good circulation. On bright, warm days we open the windows to aid in hastening the curing process. We think it essential to have a register or some such opening in the floor so the heat can pass freely into the corn room before hard freezing weather sets in. After the corn is thoroughly dried there is not much danger in freezing.

When selecting corn at husking time we place it immediately in this room and keep it there on the ear until spring.

We have stored our corn in this way for many years and have never had seed fail to grow, and generally, it has been of strong germination.

In cultivating the corn our motto is clean, shallow cultivation.

Our Minn. No. 13 corn averaged 70 bushels of shelled corn per acre in 1906.



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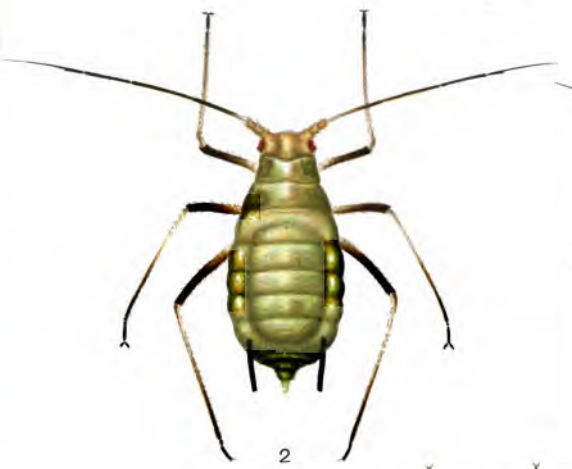

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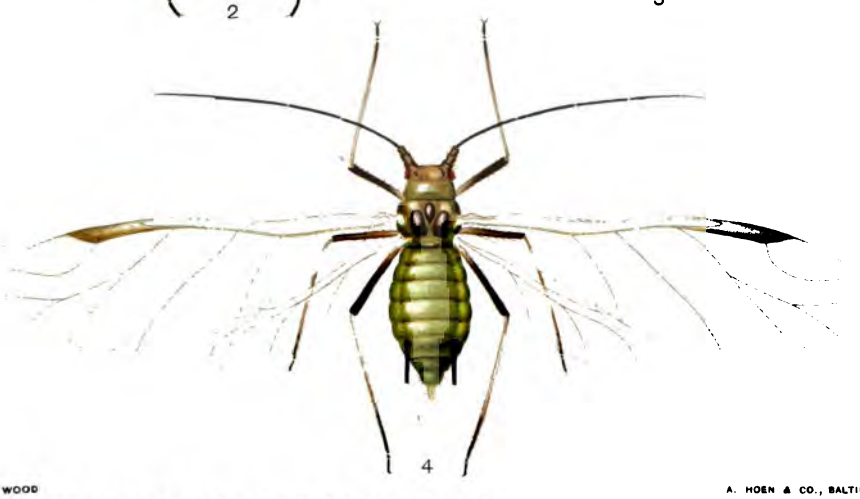

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L. L. WOOD

A. HOEN & CO., BALTIMORE

THE SOUTHERN GRAIN APHIS, OR SO-CALLED "GREEN BUG," 1, 3, AND A NATIVE FORM, MACROSIPHUM GRANARIA, 2, 4, COMMON IN MINNESOTA.

Reprint of Bulletin No. 108 of this Station.

THE SO-CALLED "GREEN BUG" AND OTHER GRAIN APHIDS IN MINNESOTA IN 1907.

F. L. WASHBURN.

GENERAL REVIEW OF CONDITIONS IN THIS STATE; FOOD PLANTS, FIELD WORK, ETC:

The unusually mild winter and cool spring of 1907 in the southern states, enabling the "green bug" to multiply without interruption from its parasite, were the causes of the outbreak last season in the South. Minnesota has long cold winters and warm summers. The first factor renders it impossible for this pest to multiply in the winter or early spring as it does in parts of the South. The second factor is favorable for the rapid increase of its principal parasite, which is found in this state, and which even in the South in ordinary years, keeps the pest in check. Therefore, in all probability, the Northwest will never have cause to fear an outbreak of the "green bug," or any other louse affecting grain.

Not since "grasshopper times" has an insect caused so much excitement in this state as did the "green bug" last summer. The conditions were remarkable in that, as in our recent financial panic, the scare was largely artificial. The insect flourished in the wheat pit, and afforded a fine club in the hands of those who would bull the price of grain. So-called "crop experts" sent into the field by railroads and other parties, apparently vied with each other in sending in alarming reports. To our certain knowledge, at least one party (and there were doubtless many others) was sent from Chicago through Minnesota

and the Dakotas, and was paid to send in lurid accounts of the work of the green bug. Early in spring, at the time the seriousness of the situation in Kansas, Texas, and Oklahoma was becoming apparent, it hardly seemed possible that the pest would reach Minnesota that season; and even if it did, the entomologist claimed, in all probability it would do no actual harm to the wheat crop. It *did reach here, but, as was prophesied, it did not affect the wheat crop.* It did, however, have a disturbing affect upon the market, partly because many of the observers, including many grain buyers and sellers were actually deceived by the close resemblance between a native, northern grain aphis, *Macrosiphum granaria,* and the southern or spring grain aphis, *Toxoptera graminum,* the so-called green bug. We use the terms "native" and "northern," in this connection merely to contrast the two forms. As a matter of fact *M. granaria* was undoubtedly originally a European or English form. Some writers here refer to it as "the English Grain Louse." This similarity is well shown in the colored plate at the beginning of this bulletin. There were others, as intimated at the beginning of this article, to whom, for trade reasons, everything on the grain was a "green bug."

Our farmers and citizens generally, seeing lice on the heads of wheat, and calling all insects by the popular term "bugs," and noting further that they were green, at once cried "Green Bugs!" At that time, owing to tense conditions in this direction, every bug on wheat which was green was not *a* green bug, but *the* green bug, and immediately startling headlines appeared in our daily and county papers, causing anxious hours for wheat raisers, and filling the heart of many a speculator with unspeakable joy.

Two trained assistants, R. L. Webster, and George G. Ainslie, were detailed by the writer for field and insectary work upon this and allied insects. Later observations were carried on by Mr. R. A. Vickery, assistant in charge of the insectary.

We were repeatedly told in the early part of the game that we had "green bugs present on the Experiment Station farm, and did not know it!" We *did* have a form of grain aphid, *M. granaria,* but not until July 5th did we find at St. Anthony Park the genuine "green bug," *Toxoptera graminum,* Rond., at which time winged forms were found on corn by Ainslie. On July 6th Webster found both winged and wingless forms producing young at Hastings. Meanwhile, from the very beginning of the cry of "Wolf! Wolf!" or rather "Green bug! Green bug!" we had kept quite constantly one, and frequently two experts in the field patrolling our southern border. These men were entomologists, and could, by using their magnifying glasses, at once distinguish the southern visitor from our more common northern form. Reports from them either by letter or wire were received almost daily, and, up to the

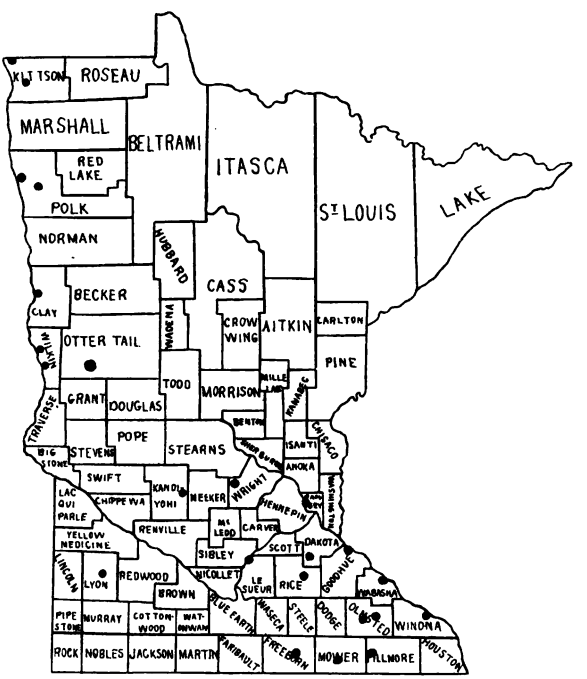

Fig. 1 Map of Minnesota. The dots show where we found the green bug, *Toxoptera graminum,* in 1907.

date mentioned above, were all of the same tenor, "No green bug here," "Plenty of Macrosiphum, no Toxoptera," etc. After the date above given, however, during the remainder of the summer, and into the autumn we found the southern form at every place visited, and doubtless it was present in small numbers almost everywhere in the grain-growing districts of the state. It was found to be present from the southern to the northern border. Webster found specimens of Toxoptera at Noyes Station, within a few hundred feet of the Canada line, opposite Emerson, Manitoba. This species was also found at Wabasha, Winona, Dover, Rochester, Spring Valley, Austin, Albert Lea, Fergus Falls, Breckenridge, Wolverton, Moorhead, Crookston, East Grand Forks and Hallock, and also at Robbinsdale, Cokato, Atwater, Marshall, LeSueur, Northfield, and Farmington. It was found commonly upon corn and oats, less frequently upon wheat. It was found on Blue grass at St. Anthony Park, July 5th, and on Timothy, July 6th; on millet at Moorhead, July 31st, and on barley at St. Anthony Park, September 1st.

The same parasite that attacked *Macrosiphum granaria* (*Lysiphlebus tritici*) also attacked Toxoptera. Parasitized specimens of Toxoptera were found at Moorhead and other places, which, no doubt, owed their death to this species. Many specimens of this parasite were reared in the insectary during the season.

Toxoptera when found on corn, was always on the under side of the lower leaves; on wheat, oats, and other grains and grasses, on the leaves, both on the upper and under surfaces. This insect was never found, according to reports of our field workers, on heads of any of its food plants, differing in this respect from *Macrosiphum granaria*, which attacks the heads as soon as they appear.

On September 1st at St. Anthony Park, Webster found numerous adults of Toxoptera inside the sheath of a barley plant. The last occurrence of Toxoptera in the field, according to notes, was on September 17th, when it was found on rye at St. Anthony Park. In this instance a

single apterous form was found on the inner surface of a rye blade. *No sexual forms were found outside at any time* though search for them was kept up late into the autumn. We had no difficulty, however, in getting these forms in the insectary, and securing eggs from them. These eggs have been placed out of doors to determine whether, or not they can survive our winters. Although Toxoptera was not found out doors in this state later than September 17th, it was probably because we did not have time to search for it thoroughly enough. After the ripening of small grain and maturing of corn, the green bug normally migrates to volunteer grain and grasses, and later, when the cold weather comes in October the eggs are laid on grasses or on winter grain, although young are probably produced viviparously up to the time of zero weather. These conclusions are based on the insectary experiments, which were carried on at outdoor temperatures.

A glance at the accompanying map will show where we found Toxoptera. However, in practically every instance it was found to be far out-numbered by the northern form, which we always have with us, and what little harm was being done to wheat was caused by the latter which we call the native form, and not by the "green bug."

It will be seen that the summer's campaign was peculiar in being directed not against the bug itself, but against the disquietude and anxiety caused the farming community and others largely by the unscrupulousness of parties who, for personal gain, sought to keep the agitation at fever heat. Doubtless the same scare, or practically a similar one, will be made use of the coming season, with the same selfish ends in view. It is to be hoped that our farmers will not be unnecessarily worried by the time-worn artifices of the speculator. However, in considering the conditions in Minnesota, we must not lose sight of the fact that Kansas, Texas and Oklahoma did suffer materially last season from this source, acres of wheat turning brown under the persistent attacks of the rapidly multiplying hordes of lice, and in the southern states apparently,

Fig. 2 A viviparous female of *Macrosiphum granaria*, with her newly born young, on leaf of barley. These young lice are all females, and each, when a few days old, will begin to produce more females as abundantly as in generation illustrated. Drawn from life. Original.

when climatic conditions are especially favorable, the advent of the "green bug" will be regarded with well-grounded anxiety. Like other aphids Toxoptera inserts its beak below the surface, and by sapping the vitality of the plant will either kill the plant outright, whole fields turning brown as a result of their work, or the plant will be dwarfed, either producing no heads or small heads without kernels. Orchard grass (*Dactylus glomeratus*) appears to be very attractive to these insects.

History of the Green Bug in the Southern States, Including the 1907 Outbreak; Europe Its Original Home.

Toxoptera graminum, Rond., was reported in Europe for the first time in 1852, in which year it was described in an Italian journal under the name of *Aphis graminum* by Dr. C. Rondani. It was reported then as feeding on oats, wheat, spelt, various grasses and corn. In 1863 it was redescribed by Passerini and placed in Koch's genus *Toxoptera.* In 1884 it was reported as infesting parts of Hungary, and referred to as one of the most destructive enemies of barley in that country. As far as known it first occurred in the United States in 1882. We have no absolute proof that this insect was brought to us from southern Europe beyond the fact as emphasized by Pergande (Bul. No. 38, Bureau of Entomology, U. S. Dept. Agric., 1902) that if it were indigenous we would have observed it upon grain from the earliest time grain was grown here, whereas, it was not observed here until 1882, and then in states bordering upon the Atlantic Ocean.

In 1884 it was found in limited numbers on wheat in Maryland. In 1885 F. M. Webster of the U. S. Entomological Bureau, at that time stationed at Oxford, Indiana, made some interesting insectary observations upon this louse, reporting that the winged females produced from one to four young a day, while the wingless females produced more rapidly. He states that an imago female in his insectary produced "thirty-seven offspring in eighteen

days, and at the end of this time some of the offspring were themselves grandmothers!"

In 1890 it was found in injurious numbers on wheat in Indiana and in certain sections of that state the oat crop was a failure through its ravages. In the same year they were found spreading abundantly through some of the southern states, Tennessee, North Carolina, Texas, Missouri, Kentucky, and also Illinois. In 1900-1901 Texas suffered severely, as did Missouri in a less degree.

The mild winter preceding the summer of 1907 in the South, followed by a late, cool spring, conditions favorable for the increase of the green bug (it is claimed that Toxoptera will breed freely in a temperature ranging from 100°F. to below freezing) and unfavorable for its chief parasite, gave the former a splendid start, and the parasite did not do effective work in consequence until too late. Practically the same weather conditions prevailed in 1890 and 1901, the dates of the preceding outbreaks. In 1907 east central Texas first reported green bugs in January on fall oats, and by March 27th they were present in destructive numbers. An agent of the Department of Agriculture found it in Arkansas in March on wheat, also in Oklahoma. March 30th the same worker found it in Kansas. Quoting from a department report as to conditions in Kansas: "By March 27th the green bugs developed winged adults in great numbers, and *these seemed to drift northward.*" The italics are the writer's. A later report from Kansas states that winged migrants were being produced there as late as January 31, 1908. The artificial introduction of parasites into infested fields by the government was without practical results, for wherever they were introduced countless numbers of parasites were found to be already there. Oklahoma lost in 1907 through the work of the "green bug" over $10,000,000. This is a very conservative estimate.

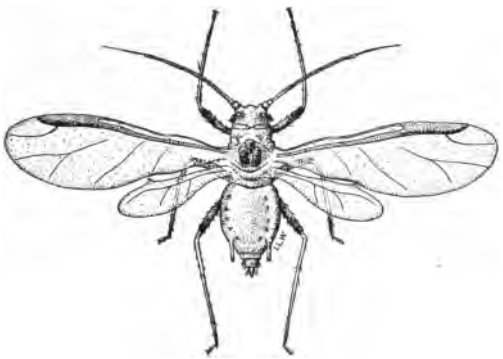

Fig. 3 Winged male "green bug." Original.

How Did the Green Bug Reach Minnesota? Its Life History.

The answer to this question involves a knowledge of the life history of plant lice in general, for they all follow

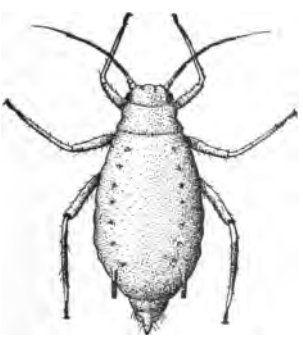

Fig. 4 Egg-laying female "green bug." Original.

Fig. 5. Eggs of "green bug" Original.

in a general way, as far as our knowledge goes, practically the same course. From the eggs in the spring hatch viviparous females, which, when they are a few days old, produce, parthenogenetically, living young (some species four or five a day) for several days before dying. These wingless young are all females (see Figs. 2 and 3 of colored plate), and each one reproduces more females in the same way, and at about the same rate. It will be readily seen that, eliminating unfavorable climatic conditions and predaceous and parasitic enemies, the descendants of one original female hatching in May would form an enormous horde of lice before September. The rapidity of increase on the part of an insect so tiny will account for the immense amount of damage done by them. Now, from time to time, instead of a wingless generation of females, we find produced *winged migrants* (Figs. 1 and 4, colored plate), and they also are viviparous females. These migrants offer the means for a wide dispersal of the pest. In the case of *Toxoptera* the withering or ripening of the grain brings out the winged migrants in rapidly increasing numbers. It was by means of these that the "green bug" reached Minnesota; not, it must be noted, by sustained flight to our state; that would be, we believe, out of the question, but more probably the winged forms borne north some distance by the prevailing southerly winds, settled on grains or grasses, started new wingless generations, which in turn produced more migrants, and these were likewise carried north, the process being repeated until we found this form (regarded as "southern") in varying numbers, not only in our fields, but even on our northern border. In the autumn true sexual forms, male and female (Figs. 3 and 4 in text) appear, and after mating eggs are laid by the female, which eggs are destined to give rise to the first females of the following spring. We have been unable to make them oviposit outside, or to find eggs which could be referred to that species, but in the insectary the sexual female (Fig. 4) laid freely on barley, placing her eggs on both dead and green leaves (see Fig. 5).

OTHER GRAIN APHIDS FOUND HERE; FIELD WORK WITH THE SAME.

FIELD WORK.—The most common grain louse, and the one generally taken for Toxoptera is *Macrosiphum granaria. This species is in general coloration a little darker green than Toxoptera, the honey tubes are in most of the stages black for their whole length, legs darker than in Toxoptera, and eyes inclined to reddish, while those of Toxoptera are black.* (See colored plate.) *In the winged migrant the discoidal vein is twice branched* (note front wings of Fig. 4, colored plate), *while in Toxoptera migrant* (Fig. 1, colored plate), *the same vein branches but once.*

On account of many people mistaking this for the southern form our two field workers, Webster and Ainslie, were detailed to make a special study of this species in the field, in connection with their observations on *Toxoptera.*

The species was first seen on May 20th at Albert Lea. At this date a single specimen was found in a field of oats east of Albert Lea by Webster. This specimen was adult and winged. On the following day winged forms and their young were found on barley at Albert Lea. From this time on until late in the fall the insect could be found either on grains or grasses. These first forms were all winged. No wingless forms at this time were found. The generation from the egg, or pseudogyna fundatrix form, is supposed always to be wingless. If this is the case with *Macrosiphum granaria,* it must have been at least the second generation, or perhaps even a later generation that was found May 20th.

On a trip made during the latter part of May and first of June, it was found at Albert Lea, Winnebago, Jackson, Worthington, Marshall and Willmar. None were found at Luverne or Pipestone at this time. In June the presence of *Macrosiphum granaria* became very noticeable in fields in the southern part of the state. At Albert Lea, June 14th, Webster found many individuals, although no appreciable damage to grain had been done at that time.

In response to a number of "green bug" reports from Winona, Dover and Rochester, an assistant was sent to that part of the state to investigate the actual conditions. This trip was made in July, a few days after the discovery of *Toxoptera graminum* in Minnesota. At Hastings, Wabasha and Winona *Macrosiphum granaria* was found very numerous, and causing considerable injury in the grain fields. At Dover and Rochester, however, this insect, *Macrosiphum* was extremely abundant, especially so upon oats. At Rochester a field of oats about four miles south of town was very badly infested with the grain louse. Yellow patches appeared generally over the field where the stand was thin and plants shorter than those surrounding. In these patches the aphids were most numerous, although the field was fairly alive with the grain lice. This was the first infested field seen during this trip. Spring Valley, Austin and Albert Lea were visited on the same trip. The grain louse was found in all of these localities, but not especially numerous in any of them.

SUMMARIZING.—*Macrosiphum granaria* was found practically all over the grain-growing portion of the state. The following places were visited, and the species found in each instance: Hastings, Wabasha, Winona, Dover, Rochester, Spring Valley, Austin, Albert Lea, Owatonna, LeSueur, St. Paul, Winnebago, Jackson, Worthington, Marshall, Willmar, Fergus Falls, Breckenridge, Moorhead, East Grand Forks, Crookston, Hallock and Noyes Station near the international boundary, opposite Emerson, Manitoba. Mr. Ainslie also found *Macrosiphum granaria* at Robbinsdale, Cokato and Atwater, and Dillon found it at Hinckley, Pine City and St. Cloud.

FOOD PLANTS.—*Macrosiphum granaria* was found generally on wheat, oats, barley, corn and rye. It was found on millet (*Panicum*) and timothy at Hastings, July 6th; on quack grass (*Agropyron repens*) at Rochester, July 11th; on speltz at Rochester, July 12th; on flax at East Grand Forks, August 1st, and on pigeon grass (*Ixophorus*), August13th, at St. Anthony Park. It was also found on wild

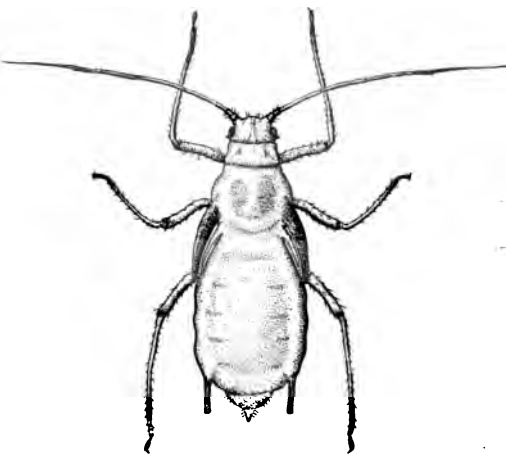

Fig. 6 Nymph of *Macrosiphum granaria,* enlarged about fourteen times. Original.

rye (*Elymus*) at Pine City, September 3rd, by Dillon, and upon *Bromus,* September 3rd, by Ainslie and Vickery at St. Anthony Park, and upon *Elymus canadensis* at St. Anthony Park, October 13th by Vickery, and on blue grass (*Poa pratensis*) by Vickery, November 7th, and upon pea. Mr. Vickery also found a viviparous female of this species producing young upon young pea, October 29th, at St. Anthony Park, and Mr. Ainslie found it upon June grass at St. Anthony Park, May 29th.

Heads of fife wheat were found to be less subject to attack by this species of aphis than heads of blue stem. On the young plants no difference was noticed in the varieties of wheat as far as susceptibility to attack was concerned. After the grain is cut or becomes ripe the lice are forced to other food plants. Pigeon grass appears to be the favorite food plant in Minnesota after harvest. This is very common in the stubble. Winter wheat and rye become infested in the fall.

When *Marcosiphum granaria* was first found in the spring it was only on the young grain plants. All the aphids at that time were found on the inner surface of the blade of the grain, none were found on the stalk of the plant itself, and few in the axils of the leaves. The aphids

continued to breed on the blades of the small grain until it began to head out, when they moved to the head. At Wabasha, on July 9th, an oat plant was found that had a single leaf blade *upon which were sixty-five grain aphids,* old and young. It was noticed that just before the plant was ready to head out the aphids were found very numerous in the axils of the leaves at the place where the head first appears. As soon as the head appears the aphids attack it.

In wheat, rye and barley the lice worked themselves down between the kernels of the head. Here they lie with the hear inward, their beaks inserted in the plant itself, taking nourishment from the head, and also producing their young. In wheat and rye heads the aphids could be easily seen in his position, but in barley heads they were less easily observed. This changing from the leaves to the heads was also true in the case of oats, where the grain lice can be easily seen upon the separate kernels.

Rye being the first grain to head out, was attacked very largely in this way. At LeSueur, June 28th, in a count of five hundred rye heads, Webster found 46.6% of the heads infested with *Macrosiphum granaria.* In a field of winter wheat six miles east of LeSueur 27% of the heads were infested when counted June 28th. Five hundred heads were counted in this case also. On July 19th, in this same field, 80% of the heads were infested, according to a count by Ainslie. On spring wheat, at LeSueur, July 19th, an average of 75% of the heads was infested with this grain aphis. Counts of infested heads on spring wheat at Cokato were made July 16th, showing 69% infested. On barley at the same place and date 48% of the heads were infested. At Atwater, July 17th, in wheat heads the infestation ran as high as 95% where the grain was dense and rank. In other parts of the fields where the wheat was shorter, the infestation ran about 20%. Barley at the same time was found infested to the extent of 25% and wheat 50% of the heads. At Marshall, on July 18th, 40% of heads of barley were found to be infested.

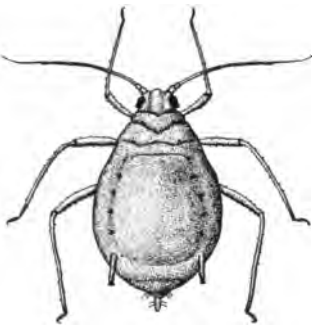

Fig. 7 Wingless viviparous female of *Siphocorynae avenae.* Original.

According to counts made by Ainslie the number of Aphids in wheat heads varied from one to twenty, the greater number of heads containing from one to five or six. On corn this aphis was found on the lower leaves, both on the upper and under sides of the leaves. In grain fields the infestation seemed to be greater on the higher and lighter soil. This was first noticed at Marshall, June 1st, in a field of oats. The aphis was found very commonly on higher ground, and only rarely on the lower ground. At Hastings this fact was also noticed. Counts of the number of infested heads in a field of rye at LeSueur, June 28th, showed 73% infested heads on high ground against 40% infested heads on low ground.

When the small grains mature this plant louse migrates to the volunteer grains and to grasses. During September it may be found on the heads and leaves of volunteer grains, *Panicum crussgalli,* Pigeon grass, and *Elymus canadensis,* as well as any young volunteer grains that may be up. It may be found on these plants during the whole fall, but as soon as the young volunteer grains and the winter wheat come up it migrates to them. The winter wheat furnishes an abundant food supply at a time when the parasitic enemies of plant lice are held in check more or less by the cold weather. The northern grain louse is thus enabled to multiply very rapidly. On the 24th of October Mr. Vickery found large colonies of apterous

females and young on winter wheat. They multiplied very rapidly, but did not become abundant enough to produce any very noticeable injury. Some parasitized individuals were present at all times, but the parasites did not become numerous enough to control the pest. On the 10th of December he collected apterous and winged viviparous females and young from winter wheat. A few Aphids could be found on almost every plant. Some parasitized individuals were found at this date. The temperature had been down as low as ten degrees above zero, and the Aphids had been covered with snow and exposed again as the snow melted. No sexual forms of the species were found, although careful search was continued until the advent of snow and ice.

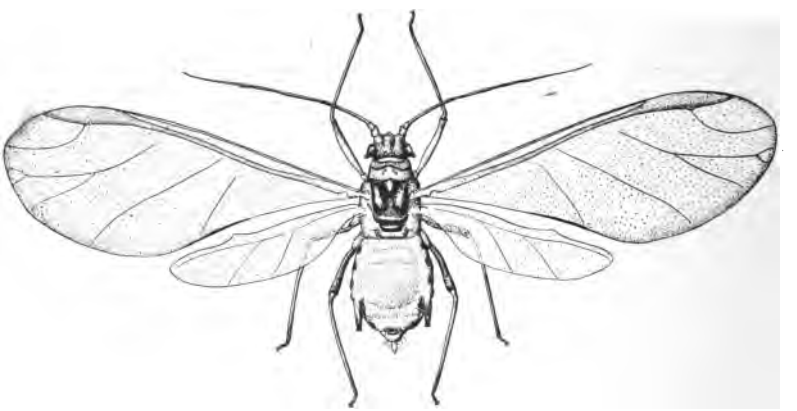

Fig. 8 Winged form, migrant, of *S. avenae.* Original.

Insectary notes show that there were at least fourteen generations up to November 8th, 1907, and that one adult may produce as many as forty-nine young. In addition to the fall food plants mentioned above, this species was also found on Poa pratensis, young timothy, fall rye and winter wheat.

Another form, common in our grain fields, is *Siphocoryne avenae,* Fab., The European Grain Louse, Figs. 7 and 8. This grain plant louse is one about which there

has been much controversy, some workers claiming that it is commonly found on the apple, it being referred to by them as the "common greenish apple aphis of the United States," which leaves the apple at about the fifth generation, and going to grains and grasses, returning to the apple in the fall, and depositing eggs thereon, which hibernate and give rise to stem mothers in the spring.

In the field we found this louse on the leaves of young wheat, oats, barley and rye during the first part of the season. Later it was found on the heads of these grains. After the small grains were cut it was found on pigeon grass and volunteer grains, and in the fall, winter wheat and rye. It occurred at Cokato, Rochester, LeSueur, Marshall, Breckenridge, Wolverton, East Grand Forks, Winnebago, Atwater, Worthington, Albert Lea and doubtless at many other places not visited.

Natural Enemies of the Green Bug and Other Grain Aphids.

All plant lice are not only influenced adversely or the contrary by weather conditions, but they are subject to the

Fig. 9 *Lysiphlebus*, sp. a parasite on grain lice, enlarged about fourteen times. Original.

attacks of numbers of predaceous and parasitic enemies. Among the former are Syrphid flies, two winged insects, which place their eggs among the colonies, the eggs hatching into hungry maggots which consume large numbers of lice. The so-called "lady birds," beetles belonging to the family *Coccinellidae,* do the same thing, their grubs or young devouring enormous numbers of aphids.

Among their parasitic enemies the most prominent, in fact *the* parasite through whose work in normal years, both *Toxoptera* and *Macrosiphum* are kept in check, is a small four-winged hymenopterous insect, *Lysiphlebus tritici* which, upon the advent of warm weather in the South last summer, rapidly increased and reduced the hordes of lice. This insect we found here, last summer, and reared it repeatedly from *Toxoptera.* Unfortunately *L. tritici* does not reproduce freely at low temperatures; below 56° F. it is said to be inactive, or, as Webster puts it, it is active only when the temperature is twenty-five degrees above that

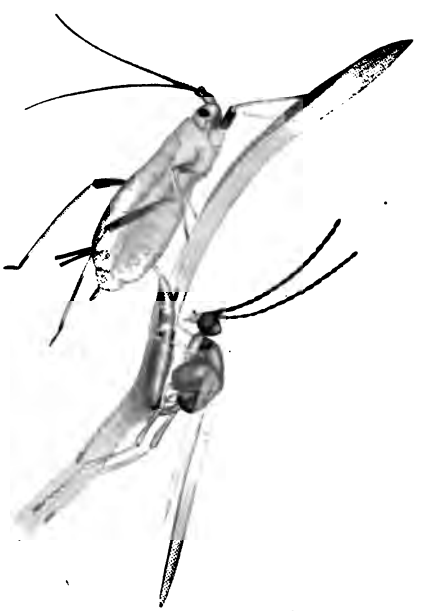

Fig. 10 *Lysiphlebus,* sp. attacking grain plant louse. From life. **Original.**

at which the green bug breeds freely. The method of attack on the part of this parasite is shown in Fig. 10, which was drawn from life by our artist, Miss Wood, and represents an individual of Lysiphlebus sp. in the act of ovipositing in a specimen of *M. granaria.* Normally *L. tritici,* as observed by us, approaches *Toxoptera* very deliberately, generally from behind, though frequently from the front, and oviposits with but little, or at least without effective resistance on the part of that louse; but *Macrosiphum* appears to be more on the defensive, and a foe requiring finer tactics. This may account for the method of attack as shown in Fig. 10. The egg placed in the body of the louse, hatches in a few days. The larva feeds upon the tissues of its host, preventing, it is claimed, any great production of young, and in this way, even before the death of its host, doing much to check the increase of the pest. Later, about a week from hatching possibly, the parasite has attained its full size, and with the proper light and magnification, can be distinguished through the body wall of its host, Fig. 11. The body of the louse swells, the individual dies, the skin darkens and hardens, and in a short time the little parasite emerges as a four-winged fly from a round hole cut in the abdominal wall of the dead insect, Fig. 12, prepared to mate and carry on the good work, if only the weather will permit. Millions of this genus of parasites are in our fields, working not only upon Toxoptera, when present, but upon some other plant lice, notably *Macrosiphum,* and in ordinary years are the principal means of keeping these pests in check. It is an encouragement to know that young lice destined to be winged, Fig. 6, are frequently parsitized; hence, when the imago migrant flies to other fields, it frequently carries the beneficial insect with it. It is worthy of note also in connection with the subject of parasitism, that *we find in Minnesota climatic conditions which are directly opposed to any disastrous outbreak of grain plant lice. In other words, we have cold winters and warm summers, the first factor preventing any undue increase of lice unattended by parasitism,*

and the warm summers allowing of a rapid increase of parasites before the lice have gained much headway.

Field observations through much of the grain-growing districts of Minnesota last summer brought out the following facts in this connection.

Eighteen per cent of the number of older aphids were parasitized in a field of rye at LeSueur, according to the counts made by Webster, June 28th. From this time on the parasites continued to increase until they reached their maximum in July. At Wabasha on July 9th 46% of the adult aphids were found parasitized and 76% were found parasitized at Dover, July 11th. At Cokato, Ainslie found 75% parasitized July 16th, and at LeSueur, July 19th, he counted 95% parasitized in a field of winter wheat. Under such heavy percentages as these the aphids could no longer withstand the attack, consequently their number decreased rapidly about this time.

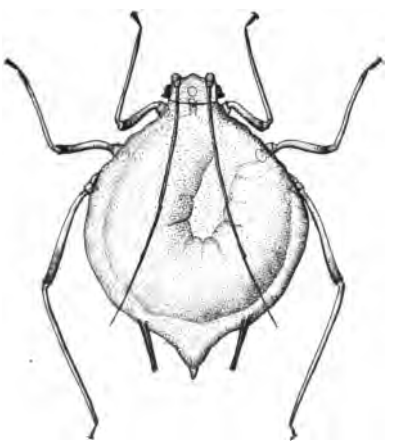

Fig. 11 A grain plant louse, *M. granaria,* in which the full grown parasitic larva can be seen. Original.

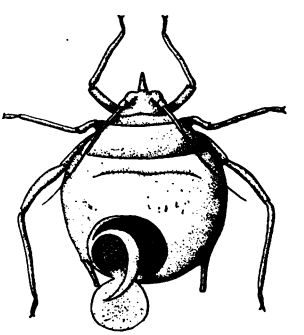

Fig. 12 A "green bug" killed by a parasite. Original.

Heavy rains in July probably gave the increase of the aphids a severe check, as well as the work of the parasites.

At Dover the grain aphis was reported very numerous on oats about July 5th. Webster visited the field

which was made the basis of our reports, on July 11th, and at this time found the insects only fairly numerous and heavily parasitized. Rains had occurred between the 5th and 11th of July, which no doubt had a part in checking the increase of the aphids. After several more rains had occurred, the same field near Dover was visited July 22nd by Ainslie, who reported that he could not find a single specimen of *Macrosiphum granaria* in this field. At Rochester a field of oats which was found very badly infested July 12th, when visited July 19th, did not show a single specimen. In the time between the two observations three heavy rains had fallen. Since only a moderate percentage of parasitism was found July 12th, the rains themselves must have killed the majority of the aphids.

Protective Measures.

Minnesotans, it would appear, need have no concern upon this point. Climatic conditions here are in our favor. It is not probable that we will ever be called upon to put in practice preventive measures in connection with either the southern form or its near ally, the northern species. The green bug in the South frequently appeared in a few spots in wheat fields, and appeared, in the beginning, to be confined to these spots. Advantage was taken of this to spread straw over these limited areas and burn same, thus killing the lice (and grain as well) and stopping their increase and spreading. They also plowed under these spots and harrowed and rolled them, packing the ground so firmly that the lice could not reach the surface. Spraying these spots with a 10% solution of kerosene emulsion was also tried with some success. It must be borne in mind, however, that even in the presence of such protection, winged migrants may come in from other non-policed fields and settle on the remaining wheat of the more careful farmer.

A weak point in the life history of *Macrosiphum* seems to be when it migrates from the mature small grains to volunteer grains and to grasses. The destruction of all

volunteer grains as well as such grasses as *Panicum crussgalli,* pigeon grass, and *Elymus canadensis,* that are found adjacent to grain fields, might considerably lessen the numbers of the aphids that would migrate to the small grains later.

Sexual Forms of Toxoptera Obtained in the Insectary.

We have not found sexual forms of the "green bug" in the field in Minnesota, nor have we been able to rear them outside in cages, but have had no trouble in getting this form in the insectary. Mr. R. A. Vickery, who has charge of our insectary work, reports them as being first found in the insectary on October 15th. They began laying eggs soon after this date, and continued for about three weeks. The winged males can be distinguished from the winged viviparous females by their somewhat smaller

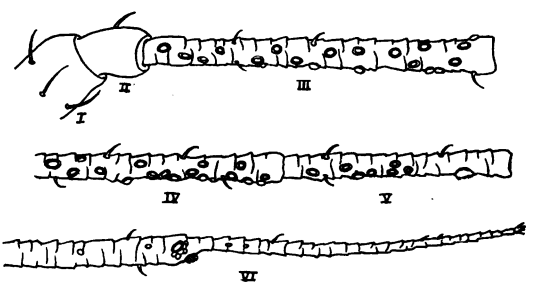

Fig. 13 Antenna of winged male *Toxoptera graminum,* x 120. Original.

size, and by the larger number of sensoria on the antennae. The oviparous females can be distinguished from the apterous viviparous females by their swollen hind tibiae, by the absence of circular sensoria on the antennae, and by the eggs which show through the abdomen as lateral, greenish yellow lines. The eggs which are bluish green when first laid, turn to a shiny black in a few days. They are about .65 mm. long, and .3 mm. broad. Most of them are laid on the upper side of the dead leaves of grain, but some are laid on the green leaves. Large numbers are placed on each leaf. Each female lays a comparatively

large number of eggs; ten nearly mature eggs were counted in one female.

Generations of viviparous females continue producing young during and after the appearance of the sexual forms. On October 25th we found on one pot of barley in the insectary males, oviparous females and eggs of Toxoptera, besides apterous and winged viviparous females and their young. Young were produced viviparously in the cold room as late as December, although the temperature had been down to ten degrees above zero. In insectary work here very few males appeared.

We append here a short technical description of the winged male and oviparous female, from specimens reared by us. This description was published in the February number of the Canadian Entomologist of the current year, and is, we believe, the first time these forms have been described.

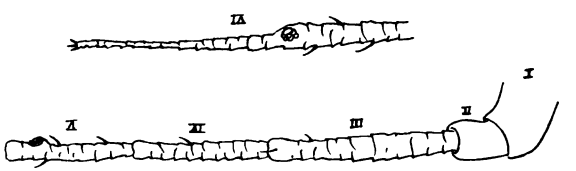

Fig. 14 Antenna of oviparous female *Toxoptera graminum*, x 120. Original.

Winged Male.—Fig. 3. Expanse of wings about 4.5 mm.; length of body about 1.3 mm. General coloration of the abdomen yellowish-green; head brownish-yellow; eyes black; antennae black, except the two basal joints and the proximal half of the third, which are yellowish-green. Legs yellow, the femora more or less dusky, the posterior pair darkest; apex of the tibiae and tarsi black; cornicles yellowish, with black apex; cauda yellowish. Wings: costa and subcosta yellow; stigma paler, the inner edge of the stigma and the veins black. Antennae long and slender, reaching to or a little beyond the end of the body; third joint with about twenty circular sensoria; fourth with about eighteen; fifth with about nine. Cauda slender, somewhat constricted about the middle, as long as the cornicles. Lateral tubercles small and single.

Oviparous Female.—Fig. 4. Length 2-2.25 mm.; color, yellowish-green, median line of abdomen darker green; head and pro-thorax somewhat paler than the rest of the body. Eyes black; antennae

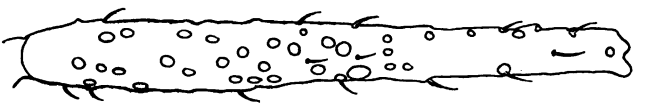

Fig. 15 Hind tibia of oviparous female *Toxoptera graminum*, x 120. Original.

black, except the two basal joints, and the basal half of the third, which are of the same color as the head. Legs yellowish, tibiae brownish toward the apex, tarsi black; cornicles greenish, their apex black; cauda greenish. Antennae slender, hardly one-half the length of the body, no circular sensoria. Cornicles slightly tapering, not reaching to the end of the body. Cauda slender, somewhat constricted above, the middle, about two-thirds the length of the cornicles. Tibia of hind leg swollen and thickly covered with sensoria-like swellings. Lateral tubercles small and single.

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SUMMARY.

1. There is choice even among good rotation schemes. In these experiments all those cropping systems gave large net profits in which corn, small grains, and timothy and clover sod laid for one to four years, were arranged in a four to seven year rotation, with light manuring once during the course.

2. The standard five year rotation followed on the check plot is: First year, corn, following the application of eight tons of manure per acre; 2nd year, wheat; 3rd and 4th years, meadow; 5th year, oats. This rotation has given an average gross income per year, based on average farm prices, of $14.08. The cost of production, including $3.50 land rental, is $9.05, leaving a net annual income of $5.03 per acre.

Several other rotation schemes were even more profitable than the one used for a standard; while crops grown continuously and crops not properly arranged in the rotation were less profitable or even resulted in a loss.

4. The best rotations in these experiments have yielded a product worth from four to six dollars per acre more than is obtained on the average farm throughout the state.

5. Many Minnesota farmers would profit were they to practice systems of cropping which include the alternation of grain crops, grass crops as clover and timothy sown together, and cultivated crops arranged in any rotation scheme best suited to their conditions.

6. The experimental evidence (see Part II.) shows that the use o fmanure and clover add to the nitrogen and that manure, also clover and timothy, add fresh vegetable matter to the soil.

7. Any systems of cropping that have provided for the maintenance of a supply of vegetable matter in the soil, either by manuring or by growing pasture or meadow crops, have given profitable returns.

8. The plots which have grown cultivated crops, such as corn, potatoes and mangels, continuously without manure, have given poorer returns than have the plots which have grown grain continuously without manure. This is believed to be due to the fact that the intertillage given these crops has caused a more rapid depletion of vegetable matter than has taken place in the continuous grain fields.

9. The four-year rotation: First year, millet; 2nd year, barley; 3rd year, corn; 4th year, oats, on Series II, Plot 5, gave no better returns than did the plot on which wheat was grown continuously. All of the crops in this rotation are considered exhaustive crops, as they all decrease rather than increase the supply of vegetable matter in the soil.

10. The practice of sowing grass seed with the grain on corn land that is disced in the spring in place of fall plowing, has resulted in securing a grass stand in nearly every instance. It has proved to be the surest method of obtaining a grass stand of any tried at University Farm.

THE ROTATION OF CROPS.

W. M. HAYS, ANDREW BOSS, A. D. WILSON.

The rotation of crops has for its object an increase in the yield per acre without a corresponding increase in the cost of production.

The experiments with crop rotations herein reported have been conducted to allow the plants grown in the ordinary field way to tell their story concerning which scheme of cropping pays best in Minnesota, and incidentally to serve in throwing light on our soil problems.

The results of the rotation experiments reported in this bulletin bear evidence that a good system of rotation will very materially increase the net earnings of many Minnesota farms.

It is believed that these preliminary ten years of experiments have given results upon which can be based a saner cropping system throughout the State.

Chemical, physical and biological studies of the soil, and experiments determining how crops yield under varying conditions, as in continuously growing a given crop, or in growing crops in rotation, are gradually unraveling the mysteries of soil fertility. The soil is so complex in its relation to crops that it has been and still is one of nature's greatest puzzles. Its solid mineral particles, making up the body of most soils, its small per cent of decaying organic substance mainly of plant origin, its water distributed in exceedingly thin films over the surfaces of the particles, its abounding species of bacteria operating in the water on the decaying plant substances and affecting the solution of the minerals, minute quantities of mineral and organic compounds in the soil water, fungus plants, and the ever acting and hungry roots of crops constantly taking in from the soil mineral and nitrogenous food and giving out solvents, make of this an almost bewildering maze of physical, chemical and biological changes. It is not strange that scientists are slow in arriving at an under-

standing of or that no one is now prepared to comprehensively state the laws of fertility. The study of the biological activities in the soil is throwing new light upon the chemistry of fertility; and the study of soil chemistry will continue to show many facts concerning the preparation and use of plant food in the soil.

Fig. 1.—General view of part of the 44 Rotation Plots.

The best rotations in these experiments have yielded a product worth from four to six dollars per acre more than is obtained on the average throughout the state. This indicates that Minnesota farmers would profit were they to practice some of the systems of rotations which these experiments have proved successful. These experiments most forcibly emphasize the fact that the application of fresh vegetable matter in the form of barn manure and clover crop residues are a necessity to keep up the productivity of the soil for cultivated and grain crops.

There is no "one" best rotation scheme. Almost all

schemes in these experiments in which grass crops were alternated with the grain and cultivated crops, and especially if barnyard manure was also applied once in several years, resulted in large yields of grain and cultivated crops, and gave large net profits per acre.

Does Continuous Cropping Exhaust Available Plant Food.

A view very generally accepted is that by the rotation of crops the soil receives a rest, that is, the plant food needed by the different crops varies, one crop removing one set of substances one year and a different crop a different set of substances the next year thus giving the soil a chance to build up for a certain crop between the years it is called upon to produce such crop. According to this contention, if a certain soil is called upon to produce the same crop or class of crops for a number of years it becomes exhausted of the particular kind of plant food needed by those crops and small yields are the result. In spite of the fact that this view is generally accepted, it is in the main doubtless incorrect. The elements of plant food which are likely to be lacking in the soil, are nitrogen, phosphoric acid and potash. According to this idea, when a soil ceases to be productive it is because it has become exhausted of the available portion of one or more of these substances. The fact that when our soils are continuously cropped to grain for several years the yield gradually decreases, and when a rotation is practiced, the yields are maintained or increased, might easily lead one to accept the above explanation. However, the following table based on actual crop yields shows that more of these elements are removed by the rotation than by the continuous cropping to wheat.

TABLE XLI.—Rotation Removes More Mineral Plant Food than Does Continuous Cropping to Wheat.

FIVE YEAR ROTATION. SERIES III. PLOT 1.			FERTILITY REMOVED		
Year	Crop	Yield	Nitrogen	Phosphoric Acid	Potash
1900	Wheat	23.3 bu.	40.8 lbs.	23.3 lbs.	40.8 lbs.
1901	Meadow	3.2 tons		76.8 lbs.	177.6 lbs.
1902	Meadow	2 1 tons		50.4 lbs.	116.3 lbs.
1903	Oats	59.0 bu.	59.0 lbs.	21.2 lbs.	53.1 lbs.
1904	Corn	58.3 bu.	96.8 lbs.	25.8 lbs.	77.4 lbs.
Total Fertility removed in 5 years			196.6 lbs.	197.5 lbs.	465.2 lbs.
Fertility added by 8 T. manure			81.6 lbs.	56.0 lbs.	81.6 lbs.
Total lost by rotation			115.0 lbs.	141.5 lbs.	383 6 lbs.
WHEAT CONTINUOUSLY SERIES III. PLOT 2					
(Total Yields 1900 to 1904 inc. 84.6 bu.) Total Fertility Removed in Five Years			148.0 lbs.	84.6 lbs.	148.0 lbs.
Excess Removed by Rotation			*-33	56.9 lbs.	235.6 lbs.

NOTE.—The figures for determining the amount of fertility removed by the various crops were taken from Prof. Snyder's "Soils and Fertilizers." The figures for determining the amount of plant food supplied by the manure were taken from Cornell Bulletin No. 27.

No nitrogen is charged against the meadow crops as the crop was about one half timothy and one half clover, and it is assumed that the clover added as much nitrogen as both crops removed.

That the five year rotation will give larger yields and continue to keep the soil in good condition for raising crops for a much longer time than will continuous wheat growing, is not doubted. Yet the fact remains as shown by the above table that eleven pounds more phosphoric acid and forty-seven pounds more potash are removed annually by the rotation than by the continuous cropping to wheat. Nearly seven pounds more nittrogen is removed by the continuous wheat than by the rotation; that is, assuming that all of the nitrogen added by the eight tons of stable manure applied to the five-year rotation could be utilized

Fig. 2.—On the left is corn growing on one of the check plots, cropped to a five year rotation: (First year, 8 tons of manure, corn; 2nd year, wheat; 3rd and 4th years, meadow; 5th year, oats.) On the right is corn growing on a plot cropped to corn continuously, no manure. See discussion Series II, Plot 7, page 315.

by succeeding crops. It is more probable that one-third to one-half of this nitrogen would be lost by leaching and by passing off as gas. This would leave the two systems practically even so far as the nitrogen removed by the crops is concerned. The advantages of following a rotation of crops over continuous cropping must be for some other reason than that the growing of the same kind of crop continuously removes too much of some particular element of fertility .

Rotation Improves Condition of Soil.

It is well known that vegetable matter or humus improves most arable soils. It at least improves soils that are somewhat run down by grain growing. Wherever partially decayed manure or roots are found in the soil, moisture is usually present, and such material also permits a free circulation of air. The real value of this condition of the soil is explained by the following facts. In order

Fig. 3.—Growing fodder corn on newly broken alfalfa sod. Compare with Fig. 5.—Photo by H. D. Ayer.

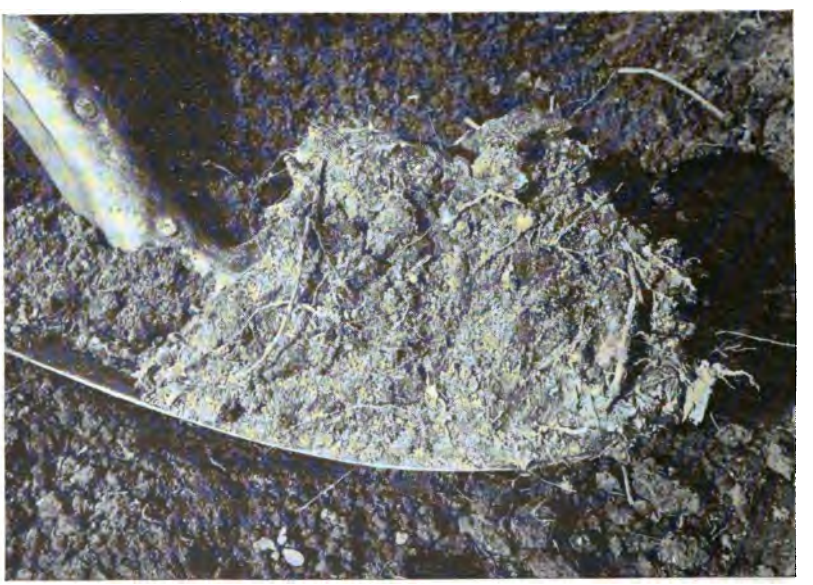


Fig. 4.—A shovelful of soil from the above plot, showing the vegetable matter present and the mellow condition of the soil. Compare with Fig. 6. Photo by H. D. Ayer.

Fig. 5.—Growing corn on plot that raises corn continuously. Compare with Fig. 3.—Photo by H. D. Ayer.

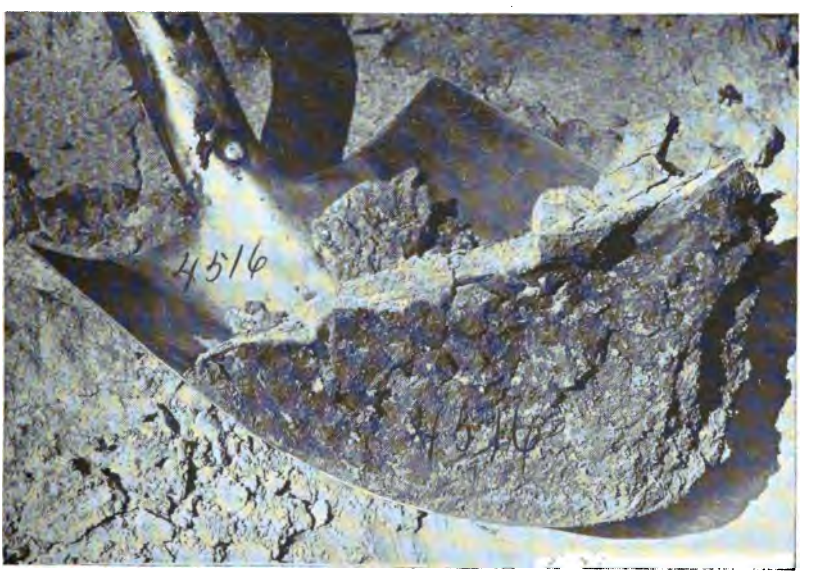


Fig. 6.—A shovelful of soil from the above plot showing lack of vegetable matter and tendency to bake.—Photo by H. D. Ayer.

to grow, plants must have food in a soluble form in contact with their roots. Plant food is made soluble by the decomposition of organic matter and disintegration of mineral matter. Disintegration of mineral matter is aided very materially by the acids formed by decomposition of vegetable matter. Decomposition of organic matter in the soil takes place as the result of the action of bacteria and the bacteria which render plant food available can act only in the presence of air and moisture. (Further discussion of the action of vegetable matter upon the soil is given in the second part of this bulletin.) Hence the necessity of effectually maintaining that condition or texture of the soil which helps regulate the supply of air and moisture. It is not assumed that a soil is inexhaustible so long as a good physical condition is maintained, but it is assumed and amply proved by results reported in this bulletin that a soil in good physical condition remains productive much longer than does a soil in poor physical condition and that maintaining a good physical condition is the most practical way known of liberating and making use of the vast stores of mineral plant food locked in the soil.

The essentials of keeping the average soil in good physical condition are, to avoid an excess of water by drainage, if necessary, and to maintain a reasonable supply of vegetable matter. Heavy soils need vegetable matter to open them up and allow the air to circulate, and light soils need vegetable matter to hold the moisture and to check leaching, and all soils need vegetable matter as a source of easily available plant food. Vegetable matter is rapidly used up in a soil on which grain or cultivated crops are grown, and is most easily added to the soil by applying barnyard manure and growing grass crops.

Professor Snyder in Minnesota Bulletin No. 24, reporting results obtained in Freeborn County from the application of special and complete fertilizers, makes the following statement: "In brief, it can be said that the commercial fertilizers did not sufficiently increase the yield to pay for the fertilizers applied, and that the yield was not increased to the same extent as on adjoining lands that were manured with farm manures and on which a rotation of crops had been practiced." From this the conclusion may be drawn, that where a naturally fertile soil is kept in good condition the necessary plant food is made available by decomposition and disintegration, and it also illustrates the fact that rotation puts the soil in the desired condition for promoting these chemical and biological changes. It is, therefore, quite evident, that one of the chief benefits of a rotation is, as has been stated, in its favorable influence upon the condition of the soil, so as to prepare the way for other changes.

It would seem then that the practical thing for the average Minnesota farmer to do is to aim to keep his soil in good condition by drainage, by good tillage and by so rotating his crops or manuring his fields, or both, as to maintain a reasonable supply of vegetable matter.

Much stress is here placed on the value of vegetable matter in the soil because the experiments herein reported indicate so conclusively that managing the soils of Minnesota so as to maintain a reasonable supply of vegetable matter will materially increase the yields, which are now far too low. Vegetable matter may be added to our soils much more cheaply than commercial fertilizers and it is earnestly hoped that our western farmers may not make the mistake made by many New England farmers who depended on commercial fertilizers until their soils no longer responded sufficiently to pay for the fertilizers applied and then were forced to abandon their farms.

Commercial Fertilizers.

There may be a few cases now and possibly more in the future where the soil is, or will become actually deficient

in some of the elements of plant food, though such a condition is not likely to occur for many years in Minnesota. It is believed by the writers that the proper attitude of the farmer in regard to commercial fertilizers is to keep his soil supplied with vegetable matter by growing grass crops and manuring, and to grow clover often enough to keep up the supply of nitrogen. He should try on small plots the application of phosphate and potash fertilizers both separately and combined. If under such conditions the application of these fertilizers increases his yields enough to pay for the fertilizers applied, he is justified in investing in commercial fertilizers.

Lime or potash fertilizers often aid greatly in the growth of clovers. In such cases their use is warranted. It sometimes requires considerable effort to get a crop of clover on a run-down soil or on soil that has not before produced clover. The great value of clover as a soil renovater and builder warrants considerable expense in getting it started. Such cases can be determined by making trials on small plots.

Three Classes of Crops.

To simplify the planning of rotations, field crops are divided into three general classes according to their effect on the physical condition and available plant food of the soil. These three classes of crops are grain crops, grass crops and cultivated crops.

Under grain crops are placed such crops as wheat, barley, oats, millet, etc. These crops grow but one season, are sown usually in the spring, and are harvested without intermediate cultivation. They do not develop heavy root systems, consequently leave but little crop residue to keep up the supply of humus in the soil. During the years when grains are grown, weeds increase and the productivity of the soil decreases.

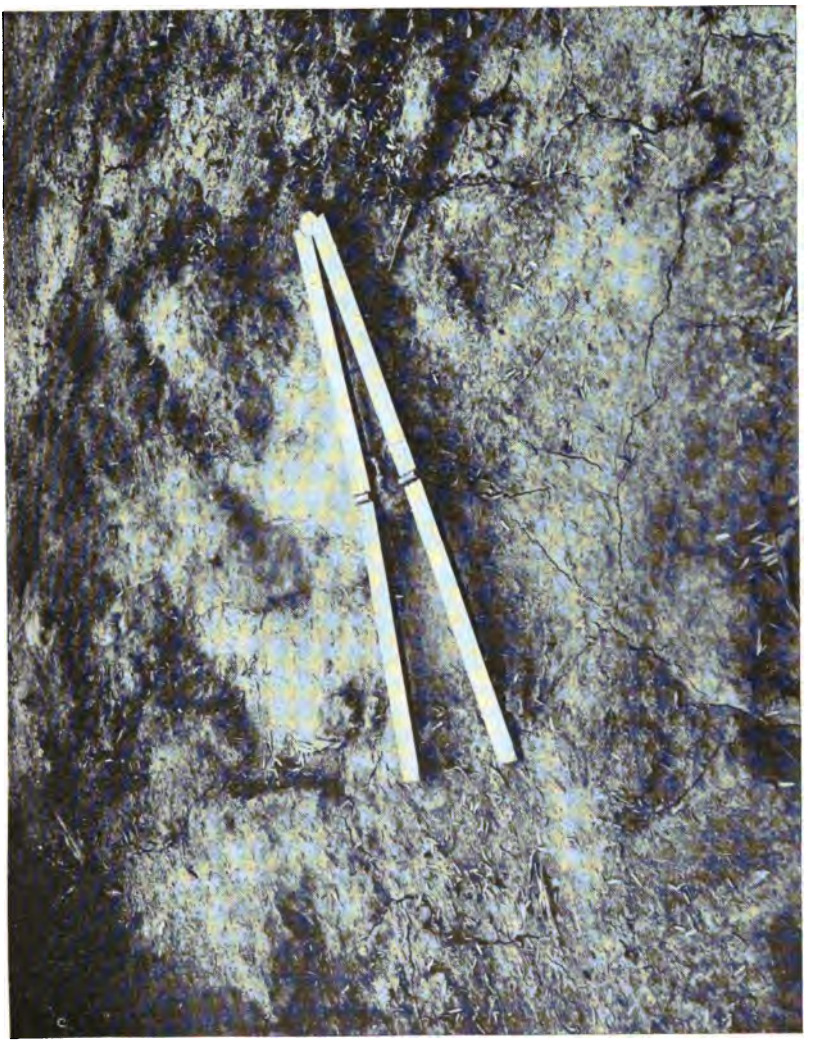


Fig. 7.—Soil as it appears after a heavy rain on a plot that grows corn continuously. The scarcity of vegetable matter allows the soil to pack so closely together as to exclude air. A soil in this condition is hard to cultivate, is likely to bake and crack, and it loses its moisture rapidly and produces small crops.—Photo by H. D. Ayer.

Fig. 8.—Soil in a corn field on a plot that grows corn once in five years, as it appears after a heavy rain. The 8 tons of stable manure added and the two crops of grass grown every five years maintain the supply of vegetable matter. As a consequence the soil remains much more mellow and more productive.—Photo by H. D. Ayer.

Grass crops include such crops as clover, (though not a true grass), timothy, bromus, etc. These crops grow two or more years from one seeding, consequently develop quite extensive root systems. When plowed up, the roots add materially to the supply of vegetable matter in the soil and in decaying leave open spaces between the soil particles which allow the entrance of air. These crops may be termed soil building crops.

The cultivated crops are those planted so as to allow intertillage during their growth. In this class are found corn, potatoes, and root crops such as mangels and sugar beets. The cultivation of these crops destroys weeds, loosens the surface of the soil, conserves moisture by the formation of a surface mulch and allows the entrance of air, thus making conditions favorable for the decomposition of vegetable matter.

It may be seen that a far better condition of soil is maintained by a good rotation of crops than by continuous cropping to corn or grain. The grass crops maintain the supply of humus and the cultivated crops retain moisture, destroy weeds and help to aerate the soil.

Instead of being a complex matter difficult to understand and impractical to follow, a systematic rotation of crops is one of the simplest and most easily carried out of any of the suggested improvements in methods of farming.

Crop Rotation Simple and Practical.

Crop rotation may be defined as a systematic succession of the three general classes of farm crops, namely, grain crops, grass crops and cultivated crops, in such a way as to provide large yields of grain, pasturage and forage needed on the farm at the least expense of labor and fertility.

Rotation systems must be adapted to each farm or class of farms and to the particular condition of each farm. With a knowledge of what it is desired to accomplish by rotation, namely an improvement in the condition of the soil and a corresponding increase in the net income per acre, it is easily possible, knowing the character of the farm, the

climate, the line of farming desired and the tastes of the farmer, to plan a systematic rotation for that farm which will give the desired results. The essentials of a good rotation are that the net yields in money value per acre be maintained or increased, that vegetable matter be kept in the soil, and that the land be kept in good physical condition and reasonably free from weeds. Grass crops must be grown or barnyard manure applied, or both, to keep up the supply of vegetable matter. A cultivated crop occasionally and good tillage are necessary to kill out weeds and help put the soil in good tilth. These things are naturally brought about by alternating the three classes of crops—that is, one or more grass crops should appear on each field every four to eight years. Corn or other cultivated crops and manure should appear one or more years in the same period, and the remainder of the time grain may be grown.

This treatment cannot fail to keep the soil in much better condition than can be done by growing any one crop continuously, and it may be brought about by a very little planning, and without very seriously changing the acreage devoted to each crop. Most farms in the middle west have from one-eighth to one-half their tillable area in corn, and from one-eighth to one-half in grass each year. All the change that is necessary is to arrange these crops according to some regular system of rotation instead of growing each on the same field year after year.

Rotation Does Not Cause Smaller Fields.

A few people hesitate to begin the rotation of crops because they have the idea that it necessitates dividing the farm into small fields. It is true that a certain number of fields are necessary to carry out a rotation. It is also true that on the average farm a good rotation will provide fewer fields and better shaped fields than are used at present under the less definite systems of cropping. (Compare Figs. 9 and 10.

The above statement is made after studying a great many farms with a view to reorganizing them for rota-

tions. If the reader will draw a rough sketch of his farm as it is cropped at the present time, showing the waste places and the areas devoted to each crop, the argument that rotation makes smaller fields than unsystematic farming will have less weight with him than at presentt.

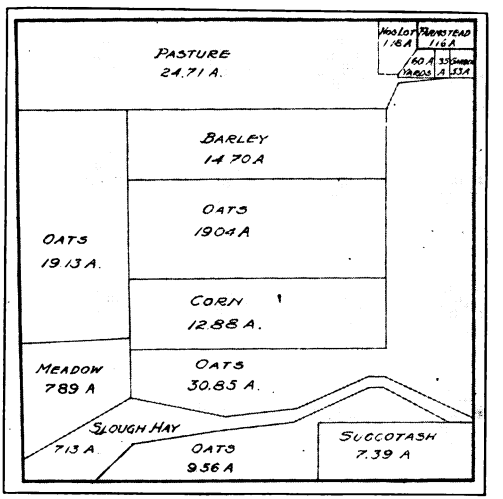


Fig. 9.—160 acre farm as cropped in 1904.

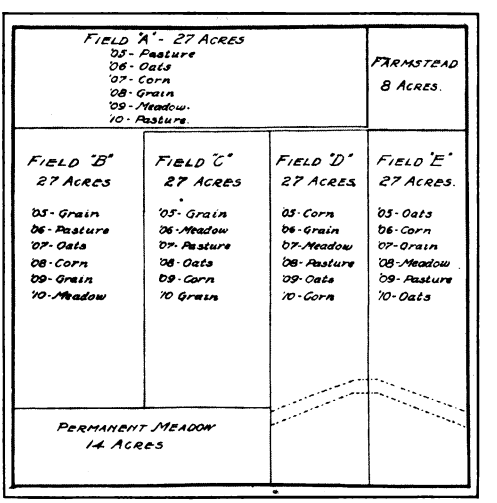


Fig. 10.—Same farm as above but remodeled for five year rotation, showing fields fewer in number, more regular and more easily reached from the farmstead.

When a plan of rotation is adopted the view of the farmer is changed. Instead of thinking only of the one crop he is seeding, he is looking ahead and planning to have that field prepared for crops one, two, or even ten years ahead. By knowing what will be sown on a field for several years in advance, labor may be saved, the yield increased, and arrangements made for making the best use of the crops grown.

Irregular Fields.

Some farms are so broken by waste land as to make the fields very irregular in shape and size. In such cases it is not easy to lay out straight, even-sized fields. Usually, by a little planning and careful management, the shape of such fields can be improved, and areas of nearly equal size can be laid off for the fields as well as on more regular farms. If necessary two smaller fields may be used as one field in the rotation.

Drainage.

One of the main causes of irregular fields is lack of drainage. Drainage is often quite expensive, and unless carefully done may be unprofitable. Yet there are few farms on which some drainage cannot be profitably done. The most annoying pieces on the farm are the low areas in the fields that can usually be plowed and seeded, but as a rule grow nothing but smart-weed or other useless plants. Such areas may be profitably drained at a comparatively high cost per acre. The cost of draining such areas may exceed the total value of the land drained and still make a profitable investment for if drained good crops could be raised without any extra cost, as it is never more work and often less work to farm a straight field than to farm around these small areas.

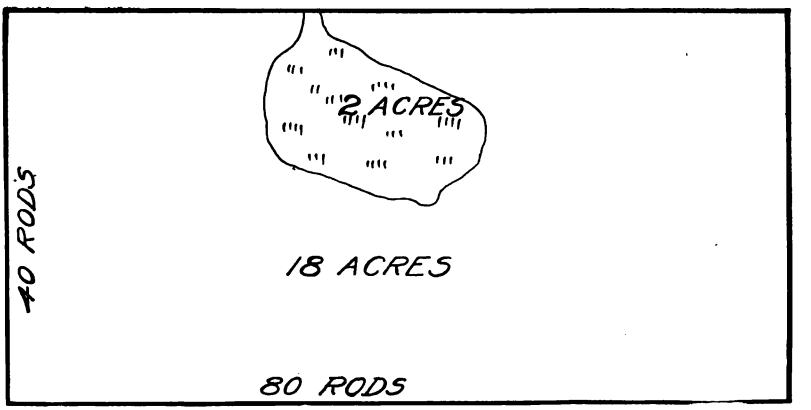


Fig. 11.—This 20-acre field could be worked as cheaply when drained as can the 18 acres now. The crop on the two acres would be clear again. Even $100 per acre for permanent drainage would be a profitable investment.

Experience in Reorganizing Farms.

In helping to reorganize for systematic rotations, the farms of some hundreds of students at the Minnesota School of Agriculture, it has been found that in most cases it is not necessary to materially change the acreage of the different classes of crops, but simply to re-arrange the sequence of the crops usually grown. Instead of growing grain and corn (humus destroying crops) continuously on one part of the farm and hay and pasture (humus forming crops) on another part, it is but necessary to alternate the crops, thus improving the condition of the soil and the prospect of good yields on all parts of the farm.

Importance of Grass Crops.

In some instances, as in the case of grain farms, it has been necessary to increase the proportion of the farm sown to grass. The continuous cropping of grain practiced so many years has reduced the amount of vegetable matter in the soil and increased the amount of weeds until the crop yields are so low as to make grain growing unprofitable. On such farms it is undoubtedly profitable to increase quite largely the proportion of the farm sown to grass, even though there is but little use for the hay, owing to the desir-

able effect the grass will have in building up and cleaning the soil. There are few cases in which roughage thus grown cannot be put to some profitable use, either by increasing the amount of livestock kept on the farm or at least buying stock cattle or sheep to feed during the fall and winter.

Decreasing Acreage of Grain Does Not Necessarily Decrease Profits.

The net profit from an acre of wheat on run down soils is very small; consequently, decreasing the acreage of wheat under such conditions will not materially decrease the net profit of the farm.

TABLE XLII.—Showing Net Profit or Loss from Yields of Wheat.

Yield	Price (a)	Value per Acre	Cost of Production including Rent (b)	Net Profit or Loss
20	$ 638	$12.76	$ 7.89	$ +4.87
16	638	10.21	7.89	+2.32
12	638	7 66	7.89	— .23
10	638	6 38	7 89	—1.51
8	.638	5 10	7.89	—2.79

(a) Average farm price December 1st for 10 years (1895-1904 inc.) as given by U. S. Dept. Year Book, 1904.
(b) Minnesota Bulletin No. 97, page 40.

From the above table it will be seen that as large a net profit is realized from one crop of twenty bushels per acre as from two crops of 16 bushels; and that a twelve bushel crop or less yields a net loss. It is a safe conclusion that seventy-five acres of grain each year on land growing a crop of clover every fourth year will yield a larger net profit than will one hundred acres sown to grain continuously.

A hay crop is one of the very cheapest crops to grow, as no extra preparation of the land or sowing is necessary, the grass seed being sown with the preceding grain crop. All the charges to be made against the grass crop are rent, cost of seed and harvesting. This is considerably lower

than the cost of growing a crop of grain or corn, hence it is not necessary that the crop yield as large a gross product in order to return equivalent net profits. Where live stock is kept grass marketed as beef, mutton, pork or milk often makes a larger net return per acre than does grain.

In addition to whatever profits may be made from the grass crop, the first grain or corn crop following it will usually yield enough more than it would following a grain crop to net as large a profit as would two low yielding crops of grain.

Rotation Experiment.

With a view to demonstrating the value and practicability of the rotation of crops, and at the same time studying various systems of rotation, the Minnesota Experiment Station laid out in 1894, 44 one-tenth acre plots for such purposes. These plots were described as follows in Bulletin No. 40 of this station:

History of 44 Rotation Experiment Plots.

"In the spring of 1894 forty-four plots each two by eight rods, one-tenth acre, were laid off on fairly uniform land on the northeast corner of University Farm. The land is a medium heavy clay loam or slightly modified till soil of good fertility, naturally well underdrained and able to retain a fairly large amount of capillary moisture throughout periods of severe drought. The plots are in four series running east and west and containing eleven plots each, these running north and south. Between each series the ends of the plots are separated by alleys a rod wide, and between each pair of plots are alleys twelve feet wide, an alley two feet wide separating the two plots of the pair. This separates the plots and enables the teamster to reach all plots in using any machine without unnecessary tramping.

"The land on which these plots were laid out had grown oats in 1892, barley in 1893 and had been in clover and timothy meadow during a number of years. The land

is not thought to be as uniform in quality as is desirable. Plots 1, 2, 3, and 4, series II, and plot 4, series III, are in a slight depression which we suppose gives them the advantage of more moisture in dry seasons and somewhat richer soil. Below is given a general statement of the plan of work.

"*Check or control plots.* Plots 1, 6 and 11 of each series are designated as check or control plots, thus giving twelve plots all seeded to the same practical rotation. These are in three rows, one extending along the east and one along the west end of all the series, and one through the middle, all running north and south. This plan distributes the control plots in such a manner that the yields or profits on any plot can be compared with the average from all twelve control plots or with the averages from the several control plots immediately surrounding it. On the twelve control plots the following plan of rotation has been instituted: wheat is sown the first year, and with this crop the land is seeded down by sowing with the spring wheat six pounds red clover and eight pounds timothy seed. The second and third years it is left to meadow, and the fourth year oats. The fifth and last year of the rotation corn is planted, and the land, previous to fall plowing the oats stubble for the corn, is given eight tons of barnyard manure per acre. Following the corn the wheat again begins the rotation of these same crops. These twelve control plots all being each year seeded to the same crop will give not only the average figures with which to compare the results of the different rotations, but will also give the range of variation or soil value of the plots in the field. These variations may prove very useful when summarizing the results of the experiments, and may show how great, yields and profits must differ to show a decided superiority of one crop of one rotation over another."

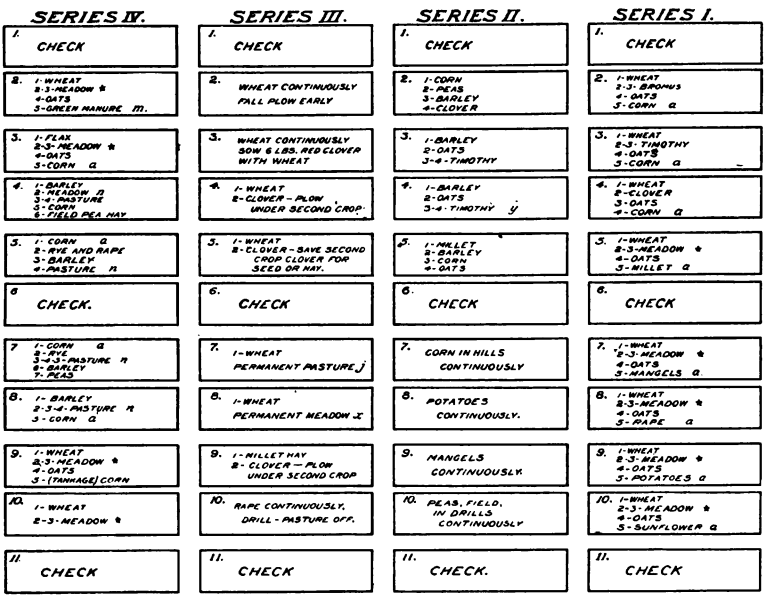

SERIES IV.
1. CHECK
2. 1-WHEAT 2-3-MEADOW * 4-OATS 5-GREEN MANURE m.
3. 1-FLAX 2-3-MEADOW * 4-OATS 5-CORN a
4. 1-BARLEY 2-MEADOW n 3-4-PASTURE 5-CORN 6-FIELD PEA HAY
5. 1-CORN a 2-RYE AND RAPE 3-BARLEY 4-PASTURE n
6 CHECK.
7 1-CORN a 2-RYE 3-4-PASTURE n 6-BARLEY 7-PEAS
8. 1-BARLEY 2-3-4-PASTURE n 5-CORN a
9. 1-WHEAT 2-3-MEADOW * 4-OATS 5-(TANHAGE) CORN
10. 1-WHEAT 2-3-MEADOW *
11. CHECK
SERIES III.
1. CHECK
2. WHEAT CONTINUOUSLY FALL PLOW EARLY
3. WHEAT CONTINUOUSLY SOW 6 LBS. RED CLOVER WITH WHEAT
4. 1-WHEAT 2-CLOVER-PLOW UNDER SECOND CROP.
5. 1-WHEAT 2-CLOVER-SAVE SECOND CROP CLOVER FOR SEED OR HAY.
6. CHECK
7. 1-WHEAT PERMANENT PASTURE j
8. 1-WHEAT PERMANENT MEADOW x
9. 1-MILLET HAY 2-CLOVER-PLOW UNDER SECOND CROP
10. RAPE CONTINUOUSLY, DRILL-PASTURE OFF.
11. CHECK
SERIES II.
1. CHECK
2. 1-CORN 2-PEAS 3-BARLEY 4-CLOVER
3. 1-BARLEY 2-OATS 3-4-TIMOTHY
4. 1-BARLEY 2-OATS 3-4-TIMOTHY y
5. 1-MILLET 2-BARLEY 3-CORN 4-OATS
6. CHECK
7. CORN IN HILLS CONTINUOUSLY
8. POTATOES CONTINUOUSLY.
9. MANGELS CONTINUOUSLY.
10. PEAS, FIELD, IN DRILLS CONTINUOUSLY
11. CHECK.
SERIES I.
1. CHECK
2. 1-WHEAT 2-3-BROMUS 4-OATS 5-CORN a
3. 1-WHEAT 2-3-TIMOTHY 4-OATS 3 3-CORN a
4. 1-WHEAT 2-CLOVER 3-OATS 4-CORN a
5. 1-WHEAT 2-3-MEADOW * 4-OATS 5-MILLET a
6. CHECK
7. 1-WHEAT 2-3-MEADOW * 4-OATS 5-MANGELS a
8. 1-WHEAT 2-3-MEADOW * 4-OATS 5-RAPE a
9. 1-WHEAT 2-3-MEADOW * 4-OATS 5-POTATOES a
10. 1-WHEAT 2-3-MEADOW * 4-OATS 5-SUNFLOWER a
11. CHECK

Fig. 12.—Showing arrangement of the 44 rotation plots, also system of cropping on each plot. The plots marked check plots, 1, 6 and 11, on each series, are cropped to the five year standard Control Rotation: first year, eight tons stable manure, corn; 2nd year, wheat; 3rd and 4th years, meadow (timothy and clover); 5th year, oats.

* Timothy 8 lbs., red clover 6 lbs.

a Eight tons stable manure per acre.

y Top dress timothy after mowing first hay crop.

j Red clover 3 lbs., timothy 4 lbs., red top 1 lb., Kentucky blue grass 7 lbs., orchard grass 3 lbs., brome grass 2 lbs., alsike 1 lb., white clover 1 lb.

x Red clover 4 lbs., alsike 1 lb., timothy 4 lbs., orchard grass 7 lbs., bromus 3 lbs.

m Plow under a crop of mixed oats and millet eartly in summer and later in fall a crop of rape.

n Timothy 8 lbs, red clover 4 lbs, alsike 1 lb.

The cut on Page 303 shows the arrangement of and the proposed rotation on each of the forty-four plots. The notes below give facts regarding grass mixtures, manuring and other special features of treatment. It will be seen from a study of this cut that a separate rotation was planned for each plot instead of using as many plots for each rotation as there are years in the rotation. This has been a saving of space which was necessary owing to a lack of land suitable for plot work, and these rotations are simply preliminary to more extensive work outlined to be carried out as soon as the land recently purchased by the University can be fitted for reliable plot work. These plots

furnish a good introduction to the study of rotation ,and have been very helpful in outlining future work. Many of the results are so pronounced and there is so much harmony of results from groups of plots that these preliminary experiments give results of large value to Minnesota.

Record Not Completed.

As was expected, an occasional mistake or a failure to get a catch of grass has prevented carrying out exactly a few of the rotations. However, they have been followed closely enough to give much valuable data, as will be observed by studying the following tables. The rotation on all the check plots, (plots 1, 6 and 11 of each series) has been carried out exactly as planned.

These rotation plots have been of great value as actual demonstration plots to visitors at University Farm. Some thousands of farmers have observed them during the growing seasons, and it is believed that no one sees them without getting a much clearer conception of the real value and practicability of the rotation of crops. Simply to observe the growing crop on Series II, Plot 7, which grows corn continuously, and a crop of corn on any of the plots on which the crops are rotated is convincing evidence of the value of rotation. The difference is readily apparent during the entire growing season. To observe the hay crop on Series III, Plot 8, which is permanent meadow, and to compare it with any plot of hay on a rotation plot, convinces one of the value of rotation meadows over permanent meadows, on land that can be broken up and that will grow other crops.

Every plot on which any crop has been grown continuously has done very poorly, comparing it with other plots in rotation, as is shown by the tabulated results:

The Cash Value of Crops.

The plots being cropped differently the same crop does not appear on all the plots the same year. It is quite impossible to compare a yield of hay with a yield of grain unless both crops are converted to terms of cash. The ob-

ject of these experiments is to determine the most profitable systems of cropping; hence it was found necessary in comparing results to establish an average farm price for all of the crops grown.

The average monthly prices of grain, for the ten years covered by this report, were obtained from the Minneapolis Chamber of Commerce reports, and from these averages reductions were made for freight, commission and elevator charges. The prices thus obtained were assumed to be the average farm prices. These prices were then compared with the December 1st farm prices given by the U. S. Department of Agriculture, and they compared so closely that it was deemed wise to use the Department prices for all products quoted in the year book.

TABLE XLIII.—The Farm Price of Farm Products December 1st each Year for the Years 1895-1904 inclusive, and Average for Ten Years (a).

Year	Wheat	Oats	Barley	Corn	Rye	Hay	Potatoes
1895	$ .44	$ .14	$ .24	$ 20	$ 28	$5 12	$ 14
1896	.68	15	.20	.19	.30	3 79	.21
1897	.77	.19	.24	.24	37	4 50	31
1898	.54	.21	.33	.24	.38	3.70	25
1899	.55	.22	.31	.24	.42	4 25	25
1900	.63	.24	38	.29	.42	6 95	30
1901	.60	.34	.45	45	.49	5 58	.67
1902	.61	.27	.37	.40	.43	5 36	31
1903	.69	.30	.37	.38	.45	6.61	61
1904	.87	.26	.42	.36	.64	5.51	29
Average 10 years	.638	.232	.331	.299	.418	5 15	.334

(a) Compiled from U. S. Dept. of Agr. Year Book for 1904.

The average prices for ten years as given above are the prices used in compiling the tables for this bulletin. As no prices were available for fodder corn and millet hay, the prices of $4.00 per ton for fodder corn and $5.15 per ton for millet hay were taken. These figures are based

on the relative feeding value of these crops compared with mixed hay at $5.15 per ton.

The Dept. year books do not give the farm price of flax so this was arrived at as follows. The price reported by the Minneapolis Chamber of Commerce for 1900 to 1904 is $1.37¾. The price in Chicago for the same years was $1.38 9/16 or a difference of 13/16 cents. The average price for ten years (1895-1904) in Chicago is $1.21 5/16 deducting 13/16 the difference between Chicago and Minneapolis prices we get the average Minneapolis price of $1.20½. Deducting the average commission, storage and dockage charges leaves the average farm price for the ten years $1.094.

The price of pasturage at 25c. per 1,000 pounds live weight per week has been arbitrarily taken, as has also the price of $1.75 per ton for mangels and 75c. per bushel for peas.

The Standard Rotation on the Check Plots.

As shown by the chart on Page 303, on Plots 1, 6 and 11 of each series, a standard five year rotation was planned. This rotation has been carried out as planned and the results show this to be a very practical rotation. It has maintained the productivity of the soil both in yields and in money value.

Table XLIV gives the crops grown each year, the yield per acre and the cash value of the crop; also the average yield and cash value per acre for the whole ten years and for the last five years of the experiment.

The average yield in cash value per acre on the three check plots of each series is a fair basis with which to compare the other rotations in the same series.

XLIV.—Yields and Cash Value of Crops on Three Check Plots on each Series.

The following standard 5 yr. rotation was followed on each of the twelve check plots, first year wheat, second and third years grass, fourth year oats, and fifth year corn.. Eight tons of barnyard manure are applied per acre to the corn crop.

SERIES I.

	PLOT 1			PLOT 6			PLOT 11		
Year	Crop	Yield	Cash Value	Crop	Yield	Cash Value	Crop	Yield	Cash Value
1895	Wheat	31.5 bu.	$20.10	Wheat	27.0 bu.	$17.23	Wheat	27.4 bu.	$17.48
1896	Tim. Clo.	3.47T.	17.87	Tim. Clo.	1.4T.	7.21	Tim. Clo.	2.35T.	12.10
1897	" "	3.35T.	17.25	" "	3.2T.	16.48	" "	3.1 T.	15.96
1898	Oats	49.7 bu.	11.53	Oats	53.9 bu.	12.50	Oats	54.2 bu.	12.57
1899	Corn	58.3 bu.	17.43	Corn	44.4 bu.	13.28	Corn	47.2 bu.	14.11
1900	Wheat	23.4 bu.	14.93	Wheat	22.6 bu.	14.42	Wheat	22.6 bu.	14.42
1901	Tim. Clo.	3.25T.	16.74	Tim. Clo.	2.75T.	14.16	Tim. Clo.	2.35T.	12.10
1902	" "	2.15T.	11.07	" "	2.37T.	12.21	" "	1.6 T.	8.24
1903	Oats	65.6 bu.	15.22	Oats	60.9 bu.	14.13	Oats	63.7 bu.	14.7
1904	Corn	51.4 bu.	15.37	Corn	39.7 bu.	11.87	Corn	56.9 bu.	17.01
Average 1895-1904			15.75			13.35			13.88
Average 1900-1904			14.67			13 36			13.31

SERIES II.

	PLOT 1			PLOT 6			PLOT 11		
Year	Crop	Yield	Cash Value	Crop	Yield	Cash Value	Crop	Yield	Cash Value
1895	Wheat	34.0 bu.	$21.69	Wheat	25.4 bu.	$16.21	Wheat	26.8 bu.	$17.10
1896	Tim. Clo.	4.47T.	23.02	Tim. Clo.	2.4T.	12.36	Tim. Clo.	2.95T.	15.19
1897	" "	3.45T.	17.77	" "	3.17T.	16.33	" "	3.32T.	17.10
1898	Oats	49.8 bu.	11.55	Oats	58.4 bu.	13.55	Oats	53.9 bu.	12.50
1899	Corn	55.5 bu.	16.59	Corn	48.6 bu.	14.53	Corn	51.3 bu.	15.34
1900	Wheat	30.8 bu.	19.65	Wheat	25.5 bu.	16.27	Wheat	22.1 bu.	14.10
1901	Tim. Clo.	4.22T.	21.73	Tim. Clo.	2.5T.	12.88	Tim. Clo.	2.8 T.	14.42
1902	" "	2.75T.	14.16	" "	1.75T.	9.01	" "	1.8 T.	9.27
1903	Oats	63.7 bu.	14.78	Oats	62.1 bu.	14.41	Oats	63.7 bu.	14.78
1904	Corn	56.9 bu.	17.01	Corn	47.9 bu.	14.32	Corn	50.0 bu.	14.95
Average 1895-1904			17.79			13.99			14.47
Average 1900-1904			17.47			13.38			13.50

TABLE XLIV—(Continued).

SERIES III.

PLOT 1				PLOT 6			PLOT 11		
Year	Crop	Yield	Cash Value	Crop	Yield	Cash Value	Crop	Yield	Cash Value
1895	Wheat	26 8 bu	$17 10	Wheat	27 4 bu	$17.48	Wheat	29 4 bu	$18.76
1896	Tim Clo	3 22T	16 58	Tim Clo	2.85T	14.68	Tim Clo	2.92T	15.04
1897	" "	3.62T.	18.64	" "	3 1 T	15.97	" "	3.15T	16.22
1898	Wheat	21.8 bu.	13.91	Oats	60 4 bu	14.01	Oats	61.8 bu	14.34
1899	Corn	57.6 bu.	17.22	Corn	50.6 bu.	15.13	Corn	58.3 bu.	17.43
1900	Wheat	23.3 bu.	14.87	Wheat	24.0 bu.	15.31	Wheat	28.6 bu.	18.25
1901	Tim. Clo.	3.2 T.	16.48	Tim. Clo.	3.0T.	15.45	Tim. Clo.	2.25T.	11.59
1902	" "	2.1 T	10.82	" "	1.7 T.	8.76	" "	2.2 T.	11.33
1903	Oats	59.0 bu.	13.69	Oats	71.2 bu.	16.52	Oats	70.0 bu.	16.24
1904	Corn	58.3 bu.	17.43	Corn	51.2 bu.	15.31	Corn	58.6 bu.	17.52
Average 1895-1904			15.67			14.86			15.67
Average 1900-1904			14.66			14 27			14.99

SERIES IV.

PLOT 1				PLOT 6			PLOT 11		
Year	Crop	Yield	Cash Value	Crop	Yield	Cash Value	Crop	Yield	Cash Value
1895	Wheat	28.1 bu.	$17.93	Wheat	23.7 bu.	$15.12	Wheat	25.7 bu.	$16.40
1896	Tim. Clo.	3.0 T.	15.45	Tim. Clo.	2.17T.	11.18	Tim. Clo.	1.74T.	8.96
1897	" "	3.4 T.	17.51	" "	3.15T.	16.22	" "	2.95T.	15.19
1898	Oats	43.4 bu.	10.07	Oats	52.9 bu.	12.27	Oats	54.5 bu.	12.64
1899	Corn	51.3 bu.	15.34	Corn	46.5 bu.	13.90	Corn	63.8 bu.	19.08
1900	Wheat	24.3 bu.	15.50	Wheat	20.3 bu.	12.95	Wheat	20.6 bu.	13.14
1901	Tim. Clo.	3.45T.	17.77	Tim. Clo.	2.1T.	10.82	Tim. Clo.	2.7 T.	13.90
1902	" "	2.05T.	10.56	" "	1.5 T.	7.72	" "	1.8 T.	9.27
1903	Oats	51 2 bu.	11.88	Oats	61.2 bu.	14 20	Oats	60.0 bu.	13.92
1904	Corn	54.0 bu.	16.15	Corn	47.5 bu.	14.20	Corn	48.8 bu.	14.59
Average 1895-1904			14.82			12.86			13 71
Average 1900-1904			14 37			11 98			12.96

TABLE XLV.—Rotations Compared with Standard Rotation.

SERIES I.

PLOTS 1-6-11				PLOT 2			PLOT 3		
Rotation Corn; Wheat; Timothy. Clover Meadow; Timothy Clover Meadow; Oats.				Corn; Wheat, Bromus Meadow; Bromus Meadow; Oats.			Corn; Wheat; Timothy Meadow; Timothy Meadow; Oats;		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Wheat	28.6 bu.	$18 25	Wheat	29.2 bu.	$18.63	Wheat	28.2 bu.	$17.99
1896	Tim. Clo.	2.41T.	12.36	Bromus	.75T.	3.86	Timothy	1.85T.	9.53
1897	" "	3.22T.	16.58	Oats	29.7 bu.	6.89	"	1.42T.	7.31
1898	Oats	52.6 bu.	12.20	Oats	65.4 bu.	15.17	Oats	65.3 bu.	15.15
1899	Corn	49.9 bu.	14.92	Corn	52.7 bu.	15.76	Corn	49.3 bu.	14.74
1900	Wheat	22 9 bu.	14.61	Wheat	22.5 bu.	14.36	Wheat	21.6 bu.	13.78
1901	Tim. Clo.	2.78T.	14.33	Bromus	1.35T.	6.95	Timothy	1.00T.	5.15
1902	" "	2.04T	10.51	"	1.92T.	9.89	"	1.15T.	5.92
1903	Oats	63 4 bu.	14.71	Oats	56.0 bu.	12.99	Oats	59.3 bu.	13.76
1904	Corn	49.3 bu	14.75	Corn	44.4 bu.	13.39	Corn	65.2 bu.	19.49
10 yr Average 1895-1904.			14.32			11.79			12.28
5 yr Average 1900-1904.			13.78			11.51			11.62

PLOT 4				PLOT 5			PLOT 7		
Rotation; Corn; Wheat; Clover Meadow; Clover Meadow; Oats				Millet; Wheat: Timothy Clover Meadow; Timothy Clover Meadow; Oats.			Mangels; Wheat; Timothy Clover Meadow; Timothy Clover Meadow; Oats.		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Wheat	30.3 bu.	$19.33	Wheat	27.1 bu.	$17.29	Wheat	24.2 bu.	$15.44
1896	Meadow	2.15T.	11.07	Tim. Clo.	3.37T.	17.36	Tim. Clo.	2.2 T.	11.33
1897	Oats	26.3 bu.	6.10	" "	3.27T.	16.84	" "	2.77T.	14 27
1898	Corn	65.2 bu.	19.49	Oats	50.3 bu.	11.67	Oats	49.6 bu.	11.51
1899	Wheat	30.5 bu.	19.46	Millet	3.00T.	15.45	Mangels	10.8 T.	18.90
1900	"	24.6 bu.	15.69	Wheat	26.6 bu.	16.97	Wheat	18.0 bu.	11.48
1901	Oats	67.2 bu.	15.59	Tim. Clo.	3.05T.	15.71	Tim. Clo.	2.05T.	10.56
1902	Corn	wt. lost		" "	2.05T	10.56	" "	1.6 T.	8.24
1903	Wheat	35.6 bu.	22.71	Oats	76.8 bu.	17.82	Oats	61.5 bu.	14.27
1904	Clover	4.75T.	24.46	Millet	2.25T.	11.59	Mangels	16.0 T.	28.00
10 yr. Average 1895-1904.			15.39			15.13			14.40
5 yr. Average 1900-1904.			15.69			14.53			14.51

TABLE XLV—(Continued).

PLOT 8				PLOT 9			PLOT 10		
Rotation: Rape; Wheat; Timothy Clover Meadow; Timothy Clover Meadow; Oats				Potatoes, Wheat; Timothy Clover Meadow Timothy Clover Meadow, Oats.			Sunflowers; Wheat; Timothy Clover Meadow; Timothy Clover Meadow; Oats.		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Wheat	25.4 bu.	$16.21	Wheat	25.9 bu.	$16.52	Wheat	26.5 bu.	$16.91
1896	Tim. Clo.	2.42T.	12.46	Tim. Clo.	2.3T.	11.84	Tim. Clo.	2.4 T.	12.36
1897	" "	2.67T.	13.75	" "	2.7T.	13.90	" "	2.6 T.	13.39
1898	Oats	55 1 bu.	12.78	Oats	54.2 bu	12.57	Oats	52.2 bu.	13.50
1899	Rape			Potato	21.0 bu	7 01	Sunflow'rs	1.4 T	
1900	Wheat	14 0 bu.	8 93	Wheat	29 3 bu	18 69	Wheat	19 1 bu.	12.19
1901	Tim Clo.	2.3 T.	11 84	Tim. Clo	2.2T	11 33	Tim Clo	2 0 T	10.30
1902	" "	1 82T.	9 37	" "	1 5T	7 72	"	1.65T	8.50
1903	Oats	60 3 bu.	13 99	Oats	60 3 bu	13 99	Oats	60 0 bu.	13.92
1904	Rape			Potato	87 1 bu	29 09	Sunflow'rs		
*Average 1895-1904,			12 42	Average 1895-1904,		14 27	Average 1895-1904,		12.63
*Average 1900 1904,			11.03	Average 1900-1904		16 17	Average 1900-1904,		11.23

* Averages 8 and 4 years respectively.

SERIES I.

Table No. XLV gives in the upper left hand corner averages of the three check plots 1, 6 and 11 of this series. The average yield in money value per acre of these three plots is $14.32. This serves as a very reliable comparison with the other plots since the three check plots are distributed over the series. All of the rotations on this series would naturally be expected to give good results since they all provide for the maintenance of the vegetable matter by growing grass crops and by the application of barnyard manure.

It was planned that all these plots be cropped under the five year rotation system, each plot varying only in one respect from the three check plots.

Plot 2. The rotation on plot 2 varies from the rotation on the three check plots by having bromus alone in

place of timothy and clover. The results from this plot are not quite so good as from the average on the check plots, which would indicate that the bromus is not as desirable a grass crop for a short rotation as is timothy and clover. A comparison of the yields of bromus on this plot with the yields of timothy and clover for the three check plots shows that the first seeding to bromus did not catch well. In fact the crop was so poor that it was plowed up the second year rather than to leave it. The second seeding of bromus in 1901 shows a rather poor stand. It gave a yield of 1.35 tons compared with an average yield of 2.78 tons of timothy and clover on the three check plots.

Plot 3. The rotation on plot 3 varies from the standard rotation by being seeded to timothy alone rather than timothy and clover. The yields of hay produced on this plot were considerably below the average yields of hay on the check plots, which accounts for the low average cash value of the product. The yields of grain following the timothy meadow are as good or a little better than the yields following the timothy and clover meadow in the standard rotation.

Plot 4. Plot 4 was planned for a five year rotation with clover alone in place of timothy and clover in the standard rotation. Owing to the fact that it is impossible to keep clover more than one year when two crops are taken, the rotation has naturally been shortened to four years, the clover having produced a crop but one year. Excellent results have been obtained from this rotation as shown by the large yield and money value per acre. Shortening the rotation to four years and manuring the corn crop each time the plot is planted to corn, increases the amount of manure applied since the plot receives eight tons of manure every fourth year instead of every fifth year. It would not be safe, however, to conclude that this is a more valuable rotation than the five year rotation, because the cost of operating the farm under this system of cropping would be greater than under the five year rotation. As it costs more to grow a grain or corn crop than to

grow a grass crop, the actual net yield in money value per acre from plot 4 is practically the same as that obtained on the three check plots.

Plot 5. The rotation on plot 5 varies from the standard rotation by having millet in place of the corn crop. Millet may very properly take the place of corn as a cleaning crop, since it is sown late in the spring giving a chance to destroy many weeds before seeding. The crop grows very rapidly and thick, thus giving very little opportunity for weeds to grow. Millet or barley might well be used in a rotation to replace corn where corn does not do well.

Plot 7. The rotation on plot 7 varies from the standard rotation by the sowing of mangels in place of corn. The yield in money value per acre is practically the same as from the standard rotation, but the net profit from such a rotation would be much less than from the standard rotation owing to the fact that it costs much more to grow a crop of mangels than to grow a crop of corn. The yields of mangels obained from this rotation are not sufficient to cover the cost of production. It is evident that mangels are harder on the soil than is corn from the yields of wheat obtained from this rotation, which follows the mangels while in the standard rotation wheat follows corn. This does not indicate that mangels are an unprofitable crop to grow, but that a five year rotation manured eight tons per acre once in five years is not a good rotation for mangels.

Plot 8. The rotation on plot 8 varies from the standard rotation by having rape in place of corn. Rape is a fairly good forage crop, but is much better adapted to use as a catch crop than as a regular crop. In this particular case no use could be made of the rape—hence no yield or value of crop was obtained.

Plot 9. The rotation on plot 9 varies from the standard rotation, having potatoes in the place of corn. This rotation has given very satisfactory results except in the yield of potatoes. The yields of potatoes obtained are not sufficient to pay for cost of production. Hence, if the

cost of production were deducted, it would not compare favorably with the standard.

Plot 10. Plot 10 varies from the standard rotation, having sunflowers in place of corn. As there is no basis on which to establish a value for this crop it has been left out. The other crops in this rotation have given fair returns.

SERIES II.

Table XLVI gives in the upper left hand corner the average yields and cash values of the crops produced on the three check plots of this series. The average cash value of the crops for ten years is $15.41. This furnishes a fair basis for comparison of the rotations on the other plots.

Plot 2. A four year rotation was planned for plot 2 consisting of corn, peas, barley and clover. This plot has given very satisfactory results as shown by the average cash value of the product which is $14.56, and is very likely a practical rotation where peas are a profitable crop. It is probable that peas will make a profitable crop wherever corn does not do well and where reasonably good crops of peas can be grown.

Plot 3 *and* 4. A four year rotation was planned for these two plots consisting of barley, oats and timothy two years. The only difference in the plots is that plot 4 is top dressed each year after the first crop of hay is cut. No appreciable difference is shown in the yields of these two plots.

Plot 5. Plot 5 has done rather better than would be expected from such a rotation. It is a rotation in one sense of the word—that is, the crops are alternated, but no provision is made for keeping up the humus supply. The yields show a tendency to gradually decrease, and will undoubtedly continue to decrease as the experiment continues. Such a system of cropping should not be confused with a practical rotation. Comparing the rotation on this plot with Plot 2, Series III which grows wheat continu-

TABLE XLVI.—Rotations Compared with Standard Rotation.

SERIES II.

PLOTS 1-6-11.				PLOT 2			PLOT 3		
Rotation: Corn; Wheat; Timothy Clover Meadow; Timothy Clover Meadow; Oats.				Rotation: Corn; Peas; Barley; Clover.			Rotation: Barley; Oats; Timothy Meadow; Timothy Meadow.		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Wheat	28.7 bu.	$18.33	Peas	20.83 bu.	$15.62	Oats	73.5 bu.	$17.05
1896	Tim. Clo.	3.27T.	16.86	Barley	47.08 bu.	15.58	Timothy	2.1 T.	10.82
1897	" "	3.31T.	17.07	Corn	44.4 bu.	13.28	"	1.97 T.	10.15
1898	Oats	54.0 bu.	12.53	Peas	28.5 bu.	21.38	Barley	54.4 bu.	18.01
1899	Corn	51.8 bu.	15.49	Peas	27.5 bu.	20.62	Oats	54.6 bu.	12.67
1900	Wheat	26.1 bu.	16.67	Barley	22.9 bu.	7.18	Timothy	1.25 T.	6.44
1901	Tim Clo.	3.17T.	16.31	Red Clo.	1.92 T.	9.89	"	1.65 T.	8.50
1902	" "	2.10T.	10.81	Corn	Wt. lost	———	Barley	43.7 bu.	14.46
1903	Oats	63.2 bu.	14.66	Peas	"	———	Oats	71.5 bu.	16.59
1904	Corn	51.6 bu.	15.43	Barley	41.2 bu.	13.63	Timothy	3.6 bu.	18.54
10 year Average 1895-1904			15.41			14.82			13.32
5 year Average 1900-1904			14.78			10.37			12.70

PLOT 4				PLOT 5			PLOT 7		
Rotation: Barley; Oats; Timothy Meadow; Timothy Meadow.				Rotation: Millet; Barley; Corn; Oats.			Rotation: Corn in hills continuously.		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Wheat	77.3 bu.	$17.93	Barley	52.0 bu.	$17.21	Corn	29.3 bu.	$ 8.76
1896	Timothy	1.77 T.	9.12	Corn	52.8 bu.	15.79	"	31.9 "	9.54
1897	"	1.95 T.	10.04	Oats	32.8 bu.	7 61	"	29.9 "	8.94
1898	Barley	53.7 bu.	17.77	Millet	2.5 T.	12.87	"	27.7 "	8.28
1899	Oats	51.7 bu.	11.99	Barley	48.1 bu.	15.92	"	20.8 "	6.22
1900	Timothy	.5 T.	2.58	Corn	45.8 bu.	13.69	"	37.5 "	11.21
1901	"	1.55 T.	7.98	Oats	70.3 bu.	16.31	"	13.9 "	4.16
1902	Barley	45.8 bu.	15.15	Millet	.82 T.	4.32	"	Wt. lost	———
1903	Oats	68.4 bu.	15.87	Barley	34.3 bu.	11.35	"	23.6 bu.	7.06
1904	Timothy	3.57 T.	18 39	Corn	44.0 bu.	13.16	"	11.1 "	3.32
10 year Average 1895-1904,			12.68			12.82			6.75
5 year Average 1900-1904,			11.90			11.77			5.15

TABLE XLVI—(Continued).

PLOT 8				PLOT 9			PLOT 10		
Rotation: Potatoes, continuously.				Rotation: Mangels continuously.			Rotation: Field Peas, sown with drill continuously.		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Potatoes	146.66 b.	$48.98	Mangels	11.1 T.	$19.42	Peas	15 5 bu.	$11.62
1896	"	11.6 b.	3.87	"	2.0 "	3.50	"	21 83 "	16.37
1897	"	86.6 b.	28.92	"	7 25 "	12.69	"	2.33 "	1.75
1898	"			"			"	15.8 "	11.85
1899	"	58.3 b.	19.47	"	13.11 "	22.94	"		
1900	"	43.8 b.	14.63	"	9.85 "	17.24	"	14.5 "	10.88
1901	"			"	4.25 "	7 44	"		
1902	"			"	5.45 "	9.54	"	7.16 "	5.37
1903	"	88.0 b.	29.39	"	6 6 "	11.55	"		
1904	"	65.5 b.	21.88	"	4.1 "	7.18	"		
7 year Average			23.88	9 year Average,		12.39	6 year Average,		9.64
3 year Average			21.97	5 year Average,		10 59	2 year Average,		8.12

ously) as nearly as the yields of different crops may be compared, shows, it is believed, the value of the classification of crops as given on Page 292. The crops on plot 5, series II are all humus consuming crops, the same as is wheat on plot 2, series III, and the fact that they have been changed about does not seem to maintain the soil in a higher state of productivity than does continuous wheat cropping.

Plot 7. The low yields of corn on plot 7 may be a surprise to many. It is generally believed that corn has a beneficial effect on the soil. It is well known that usually after a crop of corn a larger yield of grain is secured. So one might easily infer that corn is a beneficial crop and be correspondingly surprised at the low yields obtained in this experiment. It will be observed also, that this plot gives poorer returns than piot 2, Series III, on which wheat has been grown continuously. This, too, is contrary to what might generally be expected, since

wheat has the reputation of being hard on the land while corn is believed to be beneficial.

Corn is beneficial to the soil in many ways. The frequent cultivation given corn maintains during a portion of the year an effective surface mulch which aids very much in conserving moisture. The cultivation, in aerating the soil, and in conserving moisture, naturally stimulates decomposition and maintains quite effectively the conditions favorable for chemical and bacterial action. The large yields of grain usually obtained following a crop of corn show that this crop prepares the soil for other crops. The stubble and corn roots return very little vegetable matter to the soil. When corn is grown year after year on the same field the vegetable matter supply is rapidly broken down and depleted; much more rapidly than is the case with continued wheat growing, for the cultivation of the corn stimulates decomposition while in a wheat field the decomposition is less rapid.

Plot 7 has always been planted at the same time, with the same quality of seed, and has received the same cultivation as have other corn plots in the rotations, yet it has failed to give as good results. Comparing the yields of corn on this plot with the check plot beside it, plot 6, for the years the check plot produced corn, the following results are obtained:

TABLE XLVII.—Comparative Yields of Corn.

	1899	1904	Ave 2 years
Series II Plot 6, 5 yr. rotation	48 6 bu	47 9 bu	48.2 bu.
Series II Plot 7, corn continuously	20 8 bu	11 1 bu	16 0 bu.
		Gain	32.2 bu.

The yields of potatoes on plot 8 and of mangels on plot 9 tell the same story. The yields have shown a gradual decrease which is due, it is believed, to the rapid depletion of vegetable matter favored by cultivation. A

cultivated crop has about the same effect on the soil as summer fallowing.

Though it is plainly shown from table XLVI that corn continuously is hard on the soil, yet a study of the yields of other crops following corn in rotation show it to be a valuable crop in a rotation system where the vegetable matter is kept up by manure and grass crops. The growing of corn is also conducive to the keeping of livestock. This results in more manure to add to the fields. There are few of the common field crops that can be more profitably grown on a portion of the average farm in Minnesota, than corn, when manure or grass crops, or both, are used to keep up the supply of vegetable matter.

Corn has been grown successfully for several years in succession on other fields at this station, but the humus supply has been maintained by several dressings of barnyard manure.

Plots 8 *and* 9. Plots 8 and 9 have given very poor yields which can be explained in the same way in which the low yields of corn on plot 7 are explained, that is the cultivation year after year has depleted the soil of vegetable matter until it can no longer be kept in good physical condition. The high cash value for the crop on plot 8 must not be misinterpreted since the cost of production is very high for this crop.

Plot 10. Plot 10 has grown peas continuously for ten years and though the yields shown are low and several crops have been lost by unfavorable weather conditions the plot is still in fairly good condition.

Series III.

Table XLVIII gives in the upper left hand corner the average yields and cash values of the crops produced on the three check plots of this series, the average cash value of the crops for ten years is $15.40. This furnishes a fair basis for comparison of the rotations on the other plots of this series.

Plot 2. The cash value of crops grown on plot 2, which grows wheat continuously, is considerably below

TABLE XLVIII.—Rotations Compared with Standard Rotation.

SERIES III.

PLOTS 1-6-11				PLOT 2			PLOT 3		
Rotation: Corn; Wheat; Grass. Grass; Oats.				Rotation: Wheat continuously, plowed in early fall.			Rotation: Wheat continuously with 6 lbs. Red Clover Seed per acre.		
Year	Crop	Yield	Value	Crop	Yield	Value	Wheat	Yield	Value
1895	Wheat	27.9 bu.	$17.78	Wheat	24.7 bu.	$15.76	"	25.6 bu.	$16.33
1896	Tim. Clo.	3.0 T.	15.43	"	14.7 "	9.35	"	20.0 "	12.76
1897	Tim. Clo.	3.29 T.	16.95	"	17.8 "	11.36	"	22.2 "	14.16
1898	Oats	48.0 bu.	14.09	"	21.4 "	13.65	"	23.5 "	14.99
1899	Corn	55.5 bu.	16.59	"	22.5 "	14.36	"	24.0 "	15.31
1900	Wheat	25.3 bu.	16.14	"	14.5 "	9.25	"	19.8 "	12.63
1901	Tim. Clo.	2.82 T.	14.51	"	16.0 "	10.21	"	11.3 "	7.21
1902	Tim. Clo.	2.0 T.	10.30	"	17.0 "	10.85	"	15.0 "	9.57
1903	Oats	67.67 bu	15.48	"	16.3 "	10.40	"	24.1 "	15.38
1904	Corn	56.03 bu	16.75	"	20.8 "	13.27	"	32.5 "	20.74
10 year Average 1895-1904,			15 40			11.85			13.91
5 year Average 1900-1904,			14.64			10.80			13.11

PLOT 4				PLOT 5			PLOT 7		
Rotation: Wheat; Clover; second crop plowed under.				Rotation: Wheat; Clover; second crop saved for hay.			Rotation: Permanent pasture, Timothy and Clover.		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Wheat	28.2 bu.	$17.99	Wheat	30.0 bu.	$19.14	Wheat	25.3 bu.	$16.14
1896	Clover	1.42 T.	7.31	Red Clo.	2.24 T.	11.54	Pasture	1.92 T.	9.89
1897	Wheat	20.0 bu.	12.76	Wheat	20.5 bu.	13.08	"	1.17 "	6.03
1898	"	24.3 "	15.50	"	26.7 "	17.03	Wheat	19.8 bu.	12.63
1899	"	24.2 "	15.44	"	24.7 "	15.76	Pasture	data lost	———
1900	"	20.8 "	13.27	"	26.1 "	16.65	"	" "	———
1901	Clover	1.12 T	5.77	Clover	2.57 T.	13.24	"	162.3 days	5.80
1902	Wheat	18.8 bu.	11.99	Wheat	22.0 bu.	14.04	"	1.32 T.	6.80
1903	Clover	5.5 T.	28.32	Clover	5.8 T.	29.87	"	216d & 1.5T	15.44
1904	Wheat	data lost	———	Wheat	data lost	———	"	247.5 days	8.84
9 years Average,			14.26	9 years Average		16.71	8 years Average		10.20
4 years Average,			14.84	4 years Average		18.45	4 years Average		9.22

TABLE XLVIII—(Continued).

PLOT 8				PLOT 9			PLOT 10		
Rotation: Permanent Meadow, Timothy and Clover.				Rotation: Millet, Hay, Clover, second crop plowed under.			Rotation: Rape in drills continuously, pastured off		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Wheat	27.4 bu.	$17.48	Millet	2.72 T.	$12.24	Rape	11 1 T	.....
1896	Meadow	1.87 T.	9.63	"	1.75 "	7.88	"	7 3 "	.....
1897	"	2.47 "	12.72	"	Failure	.....	"	1 6 "	.....
1898	Wheat	21.0 bu.	13.40	"	2.0 T.	9.00	"	.....	.....
1899	Pasture	data lost	.....	"	1.45 "	6 52	"	.....	.....
1900	Meadow	.9 T.	4.64	"	Failure	.....	"	.....	.....
1901	"	.95 "	4.89	"	1.22 T.	5.49	"	73 days	$ 2 61
1902	"	1.27 "	6.54	"	1.7 "	7.65	"	.....	.....
1903	"	3.65 "	18.80	"	Failure	.....	"	192 days	6.86
1904	"	1.95 "	10.04	"	1 5 T	6.75	"	225 days	8 04
9 years Average			10.90	10 years Average		5 55			
5 years Average			8.98	5 years Average		3.98	3 years Average		5 84

that on plot 1, or on an average of the three check plots in this series. However the yields have held up much better than might have been expected from the practice of growing wheat continuously. The early fall plowing and good tillage have helped to keep the soil in fair condition. However, the yields of wheat in comparison to the yields on plots that are rotated are showing a gradual decrease. No other result can be expected from such practice.

Plot 3. Many grain farmers are so situated, or at least feel that they are, as to be unable to make use of enough pasture and meadow land or to produce enough manure on their farms to maintain the humus supply in their soils. The results obtained on plot 3 illustrate a practice which may be profitably followed under such conditions.

Plots 2 and 3 have received exactly the same treatment as to seed, seeding and tillage, except on plot 3 red

clover seed has been sown at the rate of six pounds per acre each spring with the wheat, and the resulting crop of clover plowed under in the fall. The yields of wheat on the two plots show an increased yield on plot 3 of 3.24 bu. per acre. The cost of that 3¼ bu. per year has been six pounds of clover seed or 90c., leaving a net profit of $1.17. While it is undoubtedly impossible to maintain the productivity of the soil in this way indefinitely and grow grain continuously, it is nevertheless a feasible proposition for the farmer who is unable to more effectively maintain the productivity by a well organized rotation. Even where rotation is practiced and where a large amount of meadow and pasture is not needed, the acreage of grain can be increased and the acreage of grass decreased if two to six pounds of clover seed per acre are sown with each grain crop. The increased yield will more than pay for the clover seed, and the improvement of the land will be a clear profit. Sowing clover seed each year with the grain will gradually inoculate the soil with clover bacteria, so that when a stand of clover and timothy for meadow or pasture is desired, the chances of obtaining it are greatly increased.

Clover sown in corn at the last cultivation has given good results. The crop may be pastured off in the fall or plowed under to increase the humus supply in the soil.

Weediness.

One of the greatest difficulties encountered by extensive wheat growers is weeds. Wild oats especially are troublesome in grain sections. This weed has very nearly taken possession of many grain fields and continues to get worse year after year. Nothing else can be expected so long as wheat or oats are grown continuously. The wild oats ripen and drop many of their seeds before the grain is cut, thus reseeding the field for the next year.

Plots 2 and 3 in this series became seeded with wild oats a few years ago, probably from the droppings of teams at work on the plots. Although these wild oats have been pulled by hand several times they are still quite

abundant. Plot 1, which is separated from plot 2 only by a two-foot alley is completely free from wild oats. The wild oats are unable to get a start on plot 1, for the corn crop once in five years cleans them out and the two years of grass also gives them no show to seed, the grass crops being cut before the wild oats can seed and most of the seeds buried by the sod lose their power to grow.

Value of Clover.

Plots 4 and 5. The value of clover is shown by the yields on plots 4 and 5. These plots, though they have received no manure nor have they grown a cultivated crop, have maintained a high state of productivity. Probably such a rotation is not practical for many farms as one-half of the farm would be producing clover. However, this rotation as actually carried out, has produced clover but three times in ten years, making an average of three-tenths of the farm in clover and seven-tenths in wheat, which is not an unreasonable proportion. The productive capacity of many of the old grain fields in the state would be greatly increased if they were sown to clover every few years. This is especially true if the clover can be fed on the farm and the manure resulting therefrom applied to the fields. The value of clover for a cleaning crop is here demonstrated. Plots 3 and 4 are separated only by a two-foot alley; plot 4 is comparatively free of weeds while plot 3 which grows wheat continuously is quite badly infested with wild oats.

Plots 7 and 8. Plots 7 and 8 on which grass has been grown continuously, have given very poor results as compared to hay grown in rotation. The yields of pasturage on plot 7 show up very well for the past couple of years, but from careful observation and from the yields of hay obtained on plot 8, it is quite evident that these pasturing results are not accurate. In fact, it is quite impossible to get accurate results from pasturing small plots. This is one thing of value that has been determined from the pasturing experiments carried out in these rotations. The tramping and discontent of the animals, when con-

fined too closely, are features that must be overcome by using larger plots.

Millet as a Nurse Crop.

Plot 9. Plot 9, on which it was intended to follow a two-year rotation of millet and clover, has failed so far to produce a crop of clover, which is due no doubt to several causes. Millet is seeded late in the spring, which is not a favorable time for sowing clover seed. Millet also is a very rank growing crop, consequently shading the ground quite thoroughly, and this plot has never appeared to be in good physical condition. All of these causes together have prevented getting a stand of clover. A good crop of clover would greatly improve the condition of this plot and if a crop is once secured, it is quite possible that this rotation might then be carried out successfully. Millet and clover together do not make a very desirable rotation, but if it is possible to get a catch of grass by sowing the seed with millet, this practice might be valuable in case of failure in a regular rotation to get a stand of grass. In such case the field could be sown to millet and grass seed. The millet would furnish the hay crop to take the place of the grass that failed, and the field would be seeded down for the next year.

The fact that millet is often used for hay leads to its being used in some cases in place of such grass crops as timothy and clover. Millet being an annual it has about the same effect on the soil as a grain crop. That is, it does not develop a heavy root system as do such biennials or perennials as timothy and clover, hence it does not increase the amount of vegetable matter in the soil. Millet should be grown for hay only as a catch crop or where the biennial and perennial grasses cannot be grown.

Rape.

Plot 10. Plot 10, as will be observed, has grown rape continuously, and though very poor results are shown from this plot, very fair crops have been grown each year. The main value of rape is as a catch crop or for

an annual pasture crop for hogs or sheep. One of the reasons why poor results were obtained on this plot is that it was not convenient to pasture the plot with either hogs or sheep. The cattle used were not as a rule used to eating rape and usually tramped it down before taking it.

Fig. 13.—Rape in corn Sept. 15th. Three lbs. of rape sown just before the corn was cultivated the last time.—Photo by H. D. Ayer.

Rape may be sown at any season of the year, and usually in six to eight weeks is from ten to eighteen inches high. The seed is cheap, costing from 5c. to 6c. per pound, and two to four pounds is ample for an acre. It has proved on other fields a valuable crop for hog pasture, and on many farms it is sown with the grain in the spring, one to two pounds per acre, to furnish fall feed for sheep or other stock. Several different times at the station, three pounds of rape per acre has been sown in the corn,—just before the last cultivation, and has given a great quantity of fall feed at a very small cost, besides preventing very largely the growth of weeds in the corn during the fall.

TABLE XLIX.—Rotations Compared with Standard Rotation.

SERIES IV.

PLOTS 1-6-11				PLOT 2			PLOT 3		
Rotation: Corn; Wheat; Grass; Grass, Oats.				Rotation: Wheat; Timothy; Clover Meadow; Timothy Clover Meadow; Oats; Green Manure			Rotation: Flax; Timothy Clover Meadow; Timothy Clover Meadow; Oats; Corn		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Wheat	25.8 bu.	$16.48	Wheat	27.9 bu.	$17.80	Flax	9.28 bu.	$10.15
1896	Tim. Clo.	2.30 T.	11.86	Tim. Clo.	2.8 T.	14.42	Tim. Clo.	3.05 T.	15.71
1897	" "	3.17 "	16.31	" "	3.27 T.	16.84	" "	3.7 "	19.06
1898	Oats	50.3 bu.	11.66	Oats	55.7 bu.	12.92	Oats	60.7 bu.	14.08
1899	Corn	53.9 "	16.11	Oats & Mil	.....	.....	Corn	53.4 "	15.97
1900	Wheat	21.7 "	13.86	Wheat	21.6 bu.	13.78	Flax	7.4 "	8.10
1901	Tim. Clo.	2.75 T.	14.16	Tim. Clo.	2.8 T.	14.42	Tim. Clo.	3.7 T.	19.06
1902	" "	1.78 "	9.18	" "	1.6 "	8.24	" "	2.4 "	12.36
1903	Oats	57.5 bu.	13.33	Oats	56.2 bu.	13.04	Oats	69.6 bu.	16.15
1904	Corn	50.1 "	14.98	Oats	30.6 bu.	7.10	Corn	.....	.....
10 years Average			13.79	10 years Average		11.86	9 years Average		14.52
5 years Average			13.10	5 years Average		11.31	4 years Average		13.92

PLOT 4				PLOT 5			PLOT 7		
Rotation: Barley; Timothy Clover Meadow; Pasture; Pasture; Corn; Field Peas for Hay.				Rotation: Corn, Rye & Rape; Barley, Timothy & Clover; Pasture.			Rotation: Corn; Rye; Pasture; Pasture; Pasture; Barley; Peas.		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Barley	47.9 bu	$15.85	Fall Rye	43.1 bu	$18.02	Fall Rye	43.1 bu	$18.02
1896	Meadow	3.8 T	19.57	Barley	39.8 "	12.78	" "	.....	.....
1897	Pasture	3.45 "	17.77	Meadow	2.51 T	12.93	Meadow	3.0 T	15.45
1898	"	2.5 "	12.88	"	2.5 "	12.88	"	2.25 "	11.59
1899	Corn	48.6 bu	14.53	"	.....	.....	Barley	41.2 bu	13.63
1900	Pea Hay	1.6 T	8.00	Fod. Corn	3.55 "	14.20	Peas	18.7 "	14.02
1901	Wheat	14.5 bu	9.25	Rye	18.6 bu	7.77	Corn	.....	.....
1902	Oat Hay	4.7 T	16.00	Barley	50.1 "	16.08	Oat Hay	4.2 T	16.80
1903	Meadow	2.45 "	12.62	Meadow	3.6 T	18.54	Meadow	3.5 "	18.02
1904	Pasture	101.2ds	3.62	Corn	46.1 bu	13.78	Pasture	95 days	3.39
10 years Average			12.96	9 years Average		14.11	8 years Average		13.82
5 years Average			9.90	5 years Average		14.07	4 years Average		13.06

TABLE XLIX—(Continued).

PLOT 8				PLOT 9			PLOT 10		
Rotation: Barley; Pasture; Pasture; Pasture; Corn.				Rotation: Wheat; Timothy & Clover Meadow; Timothy & Clover Meadow; Oats; Corn			Rotation: Wheat; Timothy and Clover Meadow; Timothy and Clover Meadow.		
Year	Crop	Yield	Value	Crop	Yield	Value	Crop	Yield	Value
1895	Barley	37.8 bu	$12.51	Wheat	23.1 bu	$14.74	Wheat	24.7 bu	$15.76
1896	"	35.0 "	11.58	Tim. Clo	1.77 T	9.12	Tim. Clo	2.47 T	12.72
1897	Pasture	1.87 T	9.63	" "	2.37 "	12.21	" "	2.9 "	14.94
1898	"	2.0 "	10.30	Oats	60.1 bu	13.94	Wheat	22.0 bu	14.04
1899	Corn	52.7 bu	15.76	Corn	43.0 "	12.86	Corn	43.0 "	12.86
1900	Barley	20.6 "	6.82	Wheat	20.1 "	12.82	Wheat	21.0 "	13.40
1901	Pasture	221 days	7.89	Tim. Clo.	1.6 T	8.24	Tim. Clo.	2.1 T	10.82
1902	Meadow	1.4 T	7.21	" "	1.75 "	9.01	" "	1.7 "	8.76
1903	"	6.2 "	31.93	Oats	54.0 bu	12.53	Wheat	22.5 bu	14.36
1904	Pasture	319.8das	11.42	Corn	34.4 "	10.29	Meadow	4.77 T	24.57
10 year Average,			12.41			11.58			14.22
5 year Average,			13.01			10.58			14.38

SERIES IV.

Table XLIX gives in the upper left hand corner the average yield and cash values of the crops produced on the three check plots of this series. The average cash value of the crops for ten years is $13.79. This furnishes a fair basis for comparison of the rotations on the other plots of this series.

Plot 2. Plot 2 has made a very good record as compared with plot 1, or compared with an average of the three check plots in this series. The average, however, is based on the average for nine years, but since the crop of 1899 was plowed under for green manure, and as that is the plan of the rotation, the total for the nine years ($117.55) should readily be divided by ten, giving an average annual crop value of $11.76. It is practical in but very few instances in Minnesota to follow the practice of green manuring. If it is decided to let a piece of land

lie idle for one year for such purpose, it is very much better where clover can be grown, to sow clover, the year before with the grain crop and plow under either the first or second crop of clover. As a rule, it does not pay to plow under either crop of clover if there is any prospect of being able to feed the clover to advantage on the farm. The manure resulting from feeding or pasturing such crops, especially if some grain is fed at the same time, is worth nearly as much to the soil as the green crop plowed under. Crops used in this way furnish roughage very cheaply.

The Flax Crop.

Plot 3. The idea that flax is a hard crop on the soil is probably a mistaken one, as shown by results on plot 3. It will be seen that this plot has given results a little better than the average of the three check plots, and but a few cents below the yearly average of plot 1, the nearest check plot.

TABLE L.—Fertility Removed by Wheat and Flax (a).

	Nitrogen. Lbs.	Phosphoric Acid. Lbs.	Potash. Lbs.
20 bu. of Wheat and Straw	35	20	35
15 bu. of Flax and Straw	54	18	27

(a) From Snyder's Chemistry of Soils and Fertilizers.

The above table shows that flax removes less phosphoric acid and potash than does wheat, but considerably more nitrogen. Nitrogen is a very necessary element of plant food, but since it is cheaply returned to the soil by the growing of clover or other legumes, the fact that a little more is removed by one crop than by another is not so important.

Flax Wilt.

One reason why flax is supposed to be hard on the soil is on account of the disease "flax wilt" which makes it impossible to grow flax for many years in succession on the same soil.

Flax wilt is a fungus disease that attacks the smaller flax plants. It lives over winter or for several years in the ground, hence when the soil is once affected it remains so for four to six years. In countries where flax is an important crop it is grown on the same field but once in five to ten years. Flax is one of our most profitable grain crops and can very well enter into a rotation on many Minnesota farms. It is not harder on the land than are other grain crops, and, as shown on plot 3, it is often a good nurse crop with which to seed grasses.

Tankage.

Plot 9. The only other plot in this series requiring any special mention is Plot 9. By looking over Fig. 12, Page 303, showing the rotation of this plot, it will be observed to be the same as the standard five year rotation except that tankage was applied to the corn instead of barnyard manure. The yields have not been so high on this plot as on the check plots. It was planned to add as much fertility in the tankage as would be added by eight tons of manure. The lower yields may be due to some inequality in the plots, but it is very likely due to lack of humus. The tankage would not increase the humus supply as much as would the manure.

PART II.

INFLUENCE OF ROTATION OF CROPS AND CONTINUOUS CULTIVATION UPON THE COMPOSITION AND FERTILITY OF SOILS.

HARRY SNYDER.

In the spring of 1892 a field that had produced small grains for about forty years was divided into six plots, and each plot was subjected to a different system of cropping. At that time and subsequently at intervals of four years samples of soil were taken from each plot and analyzed to determine the extent to which changes had occurred in the soil due to the different systems followed. The soil was quite uniform in composition and was well suited to a study of the income and outgo of fertility. In bulletins Nos. 53, 70 and 89 of this station are reported the changes in the physical properties of the soils, the losses of nitrogen and humus when grains were grown continuously and the gains when they were rotated with clover.

The experiments undertaken in 1894 were joint investigations of the divisions of Agriculture and Agricultural Chemistry. The preliminary plan of the field project is given in the Minnesota Experiment Station Report of 1893 by William M. Liggett, at that time Chairman of the Agricultural Committee of the Board of Regents and Chairman of the Station Council. A more extended discussion may be found in Bulletin No. 40. The various rotations were planned and inaugurated by Professor Willet M. Hays, while Agriculturist of the Station. The part taken by the Division of Agricultural Chemistry has been confined to a study of the income and outgo of the fertility of the plots as influenced by the different systems of cropping. The Division of Agriculture has concerned itself

with the yield and income from the different rotations. and the various problems relating to farm management.

At the close of the ten year experimental period, a large amount of analytical work in connection with these fertility studies was involved; fortunately at about this time Congress passed the Adams Act, providing funds for research work in scientific agriculture, and these investigations were made a feature under this act. Otherwise the analytical work would have progressed more slowly for lack of funds. Later the soil investigations were placed upon a more permanent basis by the University Regents establishing the Division of Soils. A small portion of the special appropriation made by the State Legislature of 1906 for Soil Investigations has also been used in connection with this work.

An extended statement of the rotations proposed and the location of the plots is given by Professor Hays in Bulletin No. 40, from which the following is quoted:

"ROTATION OF CROPS.

"The Divisions of Agriculture and Agricultural Chemistry have undertaken the joint study of the rotation of crops.

"In the spring of 1894, forty-four plots, each two by eight rods, one-tenth acre, were laid off on fairly uniform land on the northeast corner of the university farm. The land is a medium heavy clay loam or slightly modified till soil of good fertility, naturally well underdrained and able to retain a large amount of capillary moisture through periods of severe drought. The plots are in four series running east and west and containing eleven plots each, these running north and south. Between each series the ends of the plots are separated by alleys a rod wide, and between each pair of plots are alleys twelve feet wide, an alley two feet wide separating the two plots of the pair. This separates the plots and enables the teamster to reach all plots in using any machine without unnecessary tramping."

Former Results and Conclusions.

The earlier conclusions reached in studying the influence of continuous cropping and the rotation of crops upon soil fertility have been verified in the more extended series of experiments reported in this bulletin. The results obtained some fifteen years ago in a study of the fertility of native and long cultivated soils, and published in Bulletin No. 30, 1893, apply equally well to this investigation. With slight modifications and some additions, the former conclusions could consistently be repeated as those reached in the experiments reported in this bulletin. The former conclusions, Minnesota Bulletin No. 30, 1893, are as follows:

"1. Continued cropping of soils to grains only, without any system of rotation, or other treatment, is telling severely upon the original stock of half decomposed animal and vegetable matter and nitrogen. Soils which have produced grain crops, exclusively for ten or fifteen years, contain less humus and nitrogen than adjoining soils that have never been plowed.

"2. Soils which have been cropped until the organic matter and humus have been materially decreased, retain less water and dry out more readily than when there is a larger amount of organic matter present in the soil.

"3. Soils which are rich in humus contain a larger amount of phosphates associated with them in available forms than soils that are poor in humus.

"4. Soils which are rich in humus and organic matter produce a larger amount of carbon dioxide, which acts as a solvent upon the soil particles and aids the roots in procuring food.

"5. One-half of a sandy knoll, heavily manured with well rotted manure, contained nearly a quarter more water during a six weeks drought, than the other half that received no manure.

"6. The supply of organic matter in the soil must be maintained because it takes such an important part, indirectly, in keeping up the fertility. A good system of rota-

tion, including sod crops and well prepared farm manures, will do this, and will avoid the introduction and use of commercial fertilizers which are now costing the farmers of the United States over thirty-five million dollars (now eighty million) annually. It will not do to wait until this question forces itself upon us.

"7. A rotation of crops will soon be necessary on account of the peculiar composition of some of the soils and corresponding subsoils, especially those where the surface soils are richer in phosphates and nitrogen while the subsoils are richer in potash and lime. By means of rotation the full benefit of the strong points of both the top soil and the subsoil will be secured."

The decay of the humus and liberation of its nitrogen is only one of many changes that has taken place. Loss of the element nitrogen cannot be said to be the only cause of decline in fertility, as field experiments with fertilizers on old grain lands show that nitrogen alone, when added to the soil, fails to entirely restore the fertility. In addition to the decay of the humus and loss of nitrogen, the mineral elements of plant food have undergone changes in combination, the soils have become lighter in color and otherwise modified in physical properties.

To restore the fertility of the soil two methods of procedure are open: Keeping live stock with production and use of manure, or use of commercial fertilizers. The best results will probably be secured by a judicious combination of the two methods. To produce on all farms enough manure to maintain the fertility of the soil would require the keeping of a large number of live stock, and this would eventually result in over production. There are large areas of soils, originally of high fertility, where the rotation of crops, moderate use of farm manure ultimately supplemented with commercial manures will give the best financial results.

The conclusions reached in regard to the use of commercial fertilizers are given in Bulletins Nos. 94 and 102 of this Station, from which the following quotations are taken:

"Commercial fertilizers should not be used indiscriminately on old soils with a view of securing large yields, and it is not feasible by their use alone to economically restore the fertility to soils that have been impoverished by exclusive cropping to small grains. Commercial fertilizers are of great value when judiciously employed in a rotation and for encouraging the growth of legumes, as clover, so as to add nitrogen to the soil from atmospheric sources. It is believed that when they are used in this way they will prove beneficial and remunerative. Before applying them in large amounts it is recommended that farmers make preliminary trials on a small scale to determine the actual needs of the soil, so that unnecessary elements of plant food be not purchased. Commercial fertilizers cannot take the place of farm manures or crop residues, particularly those from clover and timothy, for permanently improving the soil, but they aid in the production of some crops and often assist a crop, as clover, which in turn is beneficial in adding nitrogen and humus to the soil.

"Commercial fertilizers should be used in connection with crop rotations, farm manures and clover production, rather than as the only means of increasing the fertility. When judiciously used, they have a proper place in our agriculture, but when indiscriminately applied it is generally at a financial loss."

In addition to this study of the losses of nitrogen and humus at the University Farm, similar investigations were made on a number of farms of students of the Minnesota School of Agriculture. From definitely located points in large fields samples were taken and analyzed, and after the lapse of ten years the same soils were again sampled and analyzed; the results are briefly summarized as follows:

A rotation of grain crops alone, without the production of clover or a grass crop, was found not to be sufficient to conserve the nitrogen content of the soil, even where farm manures were used. A rotation of crops, in order to be effectual, must contain clover as one of the essential parts, as a rotation of grain crops alone, without clover, may deplete the soil nitrogen more rapidly than

TABLE LI.

	Location of Soil	System of Cropping	Nitrogen Content Percent.		Estimated Loss of Nitrogen Pounds per Acre
			1895	1905	
1	Red River Valley	Grain	.601	.523	2,000
2.	Central Western part of state	A rotation of grain crops, no grass grown, manured once.	.422	.389	1,000
3	Central part of state	Similar to Farm No. 2.	.286	.247	1,200
4	Chippewa River Valley	Similar to Farm No. 2.	.363	.24	3,000
5	Central Southern part of state	Rotation of crops, clover, and farm manure used.	.31	.309	.....

continuous cultivation of one crop. It is to be noted that the losses of nitrogen from the large grain farms were practically the same as from the experimental plots at the University Farm.

The beneficial action of a clover sod, grass crop residues, and farm manures upon the soil is not alone confined to supplying nitrogen and humus-forming materials, but chemical, bacteriological and physical changes are also promoted in the soil. The studies made at this station and published in former bulletins show that chemical combination may take place between the decaying, organic compounds incorporated with the soil and the minerals. As a result of this change, plant food is made available. During the decay of animal and vegetable materials, acid products are formed which unite with the minerals of the soil, particularly with the potash and phosphoric acid forming compounds known as humates, which are valuable forms of plant food. In the absence of sufficient alkaline matter in the soil, the acid remains unneutralized and the soil unproductive, but by the addition of lime, wood ashes and other alkalies, this free acid is neutralized and the process of humus production allowed to continue. Hence it is that farm manures and grass crop residues

are valuable, not only for the fertility which they contain but also because of their favorable action upon the inert mineral matter of the soil, rendering it available as plant food. Experiments at this station have shown that the mineral matter combined with the humus may serve as plant food. Oats and wheat have been grown in which all of the mineral plant food was derived from that combined with the humus.

The indiscriminate practice of bare summer fallowing has been another cause of loss of the soil's nitrogen and humus. The occasional fallowing of land to destroy insect pests and weed seed is often necessary, but the alternation of grain and summer fallowing is particularly destructive to the humus by encouraging rapid decay with liberation of the nitrogen. Fallowing is temporarily beneficial, a few good crops being secured, but it is at the expense of permanent fertility. Experiments show that when summer fallowing is practiced five times more nitrogen is rendered soluble and available than is required for the succeeding crop; and the soluble nitrogen that is not utilized as plant food is readily lost. There is no soil so rich in nitrogen that it can endure the long continued practice of summer fallowing without ultimate decline in fertility.

Particular stress is laid upon the nitrogen and humus of the soil because they may be controlled by cultivation, and if the humus and nitrogen content is maintained the problem of fertility is greatly simplified. The maintenance of the mineral plant food of the soil cannot be neglected, but the mineral matter is not subject to such large gains and losses as the nitrogen.

On most western farms it is more economical at the present time to make the reserve mineral matter available as plant food than to purchase new stores. In many soils there is a large amount which is not in the most available forms, but is capable of being made so by cultivation. It should be the aim to keep this reserve fertility in such a condition that it will gradually become available and can be drawn upon by future crops. When the soil is

made to produce one crop year after year, there is but little opportunity for the reserve fertility to become available.

The mineral elements of plant food, it should be remembered, are present in and form a part of the microscopic soil particles. The plant obtains its food from these particles, and the less decomposed they are, the more difficult it is for the plant to utilize them. If proper means are taken, it is possible to have some mineral food in all the different stages of decomposition, so that as soon as the most available is taken up by the crop there are other forms ready to be acted upon and made available to take the place of that which has been removed. Chemical and physical changes are continually taking place in the soil, and in some soils these changes are more rapid than in others. In the cultivation of the soil it should be the aim to assist nature in bringing about those changes which render the plant food available.

While a rotation of crops in which clover forms an essential part may result in maintaining the nitrogen and humus content, there is, after a series of years, a material loss of mineral plant food, as potash and phosphate compounds. In fact, a rotation of crops removes more total mineral plant food from the soil than when a grain crop is grown continuously, and thus a rotation may hasten the exhaustion of fertility. A rotation of crops, with the occasional use of farm manures and the production of clover, will not indefinitely maintain the fertility of all soils; only those soils that are naturally fertile and contain large amounts of reserve plant food will indefinitely respond to such a system of cropping.

On some soils the rotation of crops only hastens exhaustion of the fertility by causing a larger total amount of plant food to be removed, and where large reserves do not exist in the soil the use of commercial fertilizers will be necessary. At the present time and in the case of prairie soils that are beginning to show the effects of excessive grain production, rotation of crops and the production of clover will be more beneficial than any other

means for restoring fertility. This will assist in securing larger yields for a series of years, but will not prove the final solution of the problem of maintaining the fertility of the soil.

In connection with the rotation experiments, tests have been made to determine the draft of farm crops upon the soil as to the amount of nitrogen, phosphoric acid and potash required by the plants as food. These results are published in Bulletins Nos. 29, 34 and 47. It has been found that farm crops do not remove large amounts compared with the total mineral matter in the soil, but only very small portions of the mineral elements are available as plant food at any one time. Crops make their draft upon the soil mainly in the early stages of growth, as the mineral food is required in advance of the formation of plant tissue. Growth is often checked for lack of a good supply of available plant food at the time crops are passing through their first or formative stage. A plant, like an animal, if starved while young can never regain its normal growth by later liberal feeding.

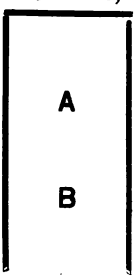
In these investigations much attention has been given to the physical condition of the soil as modified by the rotation of crops. Briefly stated, it has been found on the plots where the rotations were followed that the soils when wet are somewhat darker in color than where grain or root crops were grown continuously. The loss of humus has slightly affected the weight of the soil per cubic foot, and the apparent specific gravity, the loss not having been sufficient, however, to materially affect the absolute specific gravity. Laboratory tests show that the soils from the rotated plots respond more favorably to heat and water than the soils from the continuously cropped plots. The rotated soil plots absorb about 5 per cent more water and do not cake so badly or form as hard lumps when dry as the soils from the continuously cultivated plots. Also tests as to moisture content during periods of drought showed larger amounts of water in the rotated plots. The humus made the soils more mellow and restored that condition commonly called "good tilth."

Thorough cultivation of the soil is the first essential for the successful production of crops, and frequently this is neglected by the cultivator. Without the right kind of cultivation good seed and fertilizers will accomplish but little in the way of larger crop yields. The yields from the plots where wheat and other grains were grown continuously and in rotation were in part secured through the thorough cultivation, but cultivation alone, valuable and important as it is, will not solve the problem of better crops. Cultivation must be combined with a judicious system of manuring. During the first decade of these rotation experiments the reserve fertility of the soil has been drawn upon for maintaining crop yields, during succeeding periods the reserve fertility will become less active, and undoubtedly it will be necessary to re-enforce it with one or more of the elements of plant food, as potash or phosphates. Cultivation cannot take the place of manures, neither can manures take the place of cultivation. Both are important in crop production. It is undoubtedly the sum of all these factors, physical, chemical and bacteriological, that enables larger yields of crops to be secured from the rotated plots. It cannot be said to be due to physical conditions alone, because it is impossible to improve the physical condition of the soil without at the same time bringing about a series of chemical and bacteriological changes. There is such an intimate relation between the physical, chemical and bacteriological changes in the soil that it is impossible to cause one to take place without also influencing or inducing the others. A rational explanation of crop rotation must be founded upon physical, chemical and bacteriological grounds.

In this bulletin, special emphasis has been laid on maintaining the humus supply of the soil, because the humus acts on the soil in all of the three different ways mentioned, physical, chemical and bacteriological, and brings about desirable changes, but, as previously stated, maintaining the humus does not alone permanently solve the problem of soil fertility in connection with crop production.

Methods of Analysis.

Sampling Soils. The method of the Association of Official Agricultural Chemists was followed in sampling the soils, and the samples were taken from definitely located points. In each plot two points, A and B are located. A is situated one rod from the east and two rods from the south boundary line, while B is one rod from the east and two rods from the north boundary line. From A as a center ,and within a radius of five feet, three samples of soil were taken to a depth of six inches. In the same way three samples were taken with B as the center. These samples were mixed to form a composite sample. At both the beginning and the close of the experimental period the soils were sampled in the same way. It is believed that by taking the samples from definitely located points the difficulties in the way of securing comparable samples are reduced to a minimum. It is to be noted that in these experiments the surface soils were sampled to a depth of *six* inches while in the experiments reported in earlier bulletins the soils were sampled to a depth of nine inches. It was found that, if the samples were taken to a depth of *nine* inches, a little of the subsoil would be included in the case of some of the forty-four plots. The plots were fairly uniform, but not as uniform as those used in the earlier trials. While the rotation experiments on the forty-four plots were started in the spring of 1894, the soils were not sampled until the following year.



Nitrogen. The nitrogen was determined by the Kjeldahl method, about twenty grams of soil being used for the purpose. The method for determination of nitrogen is recognized as one of the most accurate determinations in analytical chemistry. Samples of the soils collected and analyzed in 1895 were dried and stored in glass cans. When the 1905 samples were analyzed some of these former samples were re-analyzed with the view of checking any minor errors arising from the work being done at

different times and under possibly different conditions. In all cases a reasonably close agreement of results was secured.

The nitrogen results plainly indicate that the errors arising from sampling and in the analytical work are comparatively small, and that the variations in the nitrogen content of the soils at the beginning and at the close of the experimental period are due to actual changes which have taken place in the soils and not to uncontrolable errors. In a former bulletin, No. 70, page 254, it is stated: "Since nitrogen is of so much importance in plant growth, it is essential it should be accurately determined, and while the percentage amount of the nitrogen in a soil is comparatively small, methods have been devised for determining this small amount with a high degree of accuracy. The results are given as percentage amounts; .222 per cent of nitrogen means that in 100 pounds of dry soil there are .222 pounds of nitrogen. Duplicate determinations of the same soil when carefully made, agree to within .004 of a per cent and less. Hence any material increase or decrease of nitrogen, as .01 of a per cent or more as shown by analysis is due to a loss or gain of nitrogen from the soil caused by the method of cultivation."

In order to secure data as to the influence of slight variations in the depth of sampling upon the nitrogen content of the soils, samples were taken from one of the plots to various depths, as follows:

Soil Inches	Nitrogen Per cent.
1 to 6	.242
1 to 7	.237
1 to 8	.217

The decrease in the nitrogen content of the samples of soil was nearly proportional to the increase in the depth of sampling. A change of one inch in the volume of the first seven inches affected the nitrogen results to the extent of .005 per cent. Since the soils of these experiments were sampled under similar conditions at the beginning and the close of the experiment, it is believed that any

error introduced through change of volume of soil would amount to less than an inch in depth, or .005 of a per cent.

In nitrogen determination of food materials results to the third decimal place are not reported ,as they are not generally considered by chemists to be reliable. In the case of soils, however, the results to the third place bear the same relation, as far as accuracy is concerned, as the results to the second place in the analysis of foods. An analyst is not considered as possessing a high degree of skill if he is unable to duplicate his results to within .05 of a per cent for a material containing one per cent of nitrogen. In the determination of nitrogen in foods, from .7 to 1 gram of the material is usually taken, and in the case of soils containing .2 to .3 per cent of nitrogen, from 10 to 20 grams. When the substance, as soil, contains a small per cent of nitrogen, and a large amount of the substance is used for the determination, the accuracy of the results expressed by the third decimal is proportionally increased. Lawes and Gilbert, in their extensive investigations on soil nitrogen, often report their results to the fourth decimal place, and Warington gives all of his soil nitrogen results to the third decimal place. When the soil samples are accurately and systematically taken and the analytical work is carefully done, it is believed it is safe to attribute any difference in nitrogen content of .01 of a per cent to change in nitrogen content of the soil brought about by the methods of cultivation.

Humus. No direct determinations were made of the humus content of the soils at the beginning and close of the experimental period, because the present methods for its determination are not sufficiently accurate to warrant comparisons being made where the changes in humus content amount to less than one per cent. The change in organic content of the soils was, however, determined from the gains and losses of the element carbon, which is a constituent that makes up over 50 per cent of humus. The determination of total organic carbon by combustion analysis, like the determination of nitrogen, is accurate.

When the carbon and nitrogen results are jointly considered, they show not only the amount but also the general nature of the changes which have taken place in the organic matter (humus) of the soil due to the different systems of cultivation.

The humus and organic compounds exert a modifying influence, both physically and chemically, upon the composition of the soil. Briefly stated: humus yields through processes of decay nitrogen as food for plants; it combines with the inactive mineral matter of the soil to produce humates, which are valuable forms of plant food, and when humus is incorporated in soils, there is improvement in the general physical properties or tilth. To secure the highest benefits from humus, the soil should contain a slight amount of active alkaline material which readily combines with the organic acids produced from the decay of the humus and forms humates. Excessive decay of the humus takes place in new soils that are cropped exclusively to small grains. A moderate decay of the humus is desirable, so as to render the nitrogen and mineral matter available as plant food. As previously stated, one of the chief benefits derived from rotating crops is the maintenance of a liberal supply of nitrogenous humus in the soil.

Potash and Phosphoric Acid. No attempt was made to study the total losses of phosphorus and potassium from the various plots. The soils are characterized by a high percentage of phosphorus compounds, about .20 of a per cent of phosphoric anhydrid, P_2O_5 Small crystals of apatite or phosphate rock are occasionally observed in the mechanical analysis of these soils. As the surface soils contained 4,000 pounds per acre of phosphoric anhydrid and approximately 250 pounds were removed in the ten crops, it is quite evident that the determination of the total phosphoric acid would fail to show any decline, as the amount lost would be less than the limit of error involved in its determination. In the case of the nitrogen, the losses are much greater, as it is both utilized as plant food and lost when excessive decay of the humus occurs,

the nitrogen being rendered both soluble and volatile. The changes in solubility of both the phosphorus and the potassium compounds during the ten years of different methods of cultivation were determined. The method followed, the fifth normal nitric acid, is described in the Methods of Analysis of the Association of Official Agricultural Chemists. Slight changes in the solubility of the potash compounds appear to have taken place during the ten year period, but no appreciable change in the solubility of the phosphoric acid in the dilute nitric acid seems to have occurred.

To show the general chemical composition, an analysis was made of the soil of one of the plots of each of the four series. The average of the four analyses is as follows:

TABLE LII.—Chemical Composition of Soil.

	Per cent.
Total Insoluble Matter	82.51
Potash (K_2O)	.28
Soda (Na_2O)	.18
Lime (CaO)	.57
Magnesia (MgO)	.28
Iron (Fe_2O_3)	2.79
Aluminia (Al_2O_3)	5.16
Phosphoric Anhydrid (P_2O_5)	.21
Total Volatile Matter	7.82
Total	99.80

In Tables Nos. 53, 54, 55, 56, are given the percentage amounts of nitrogen and carbon in the dry surface soils, and the phosphoric anhydrid and potassium oxide soluble in fifth normal nitric acid for the forty-four plots, at the beginning and at the close of the experimental period. The tables also give the systems of rotation followed. Credit is due Messrs. J. A. Hummel, A. D. Wilhoit and W. H. Frazier for valuable assistance rendered in the analytical work. The following tables give the composition of the soils from the forty-four rotation plots, sampled in 1895, and again in 1905 after ten years of cropping. The rotations, as originally proposed, are in the first column. In a few cases it has been necessary to slightly modify the original plans because of failure to secure a grass crop at the place desired in the rotation. These changes are indicated by foot notes. The results are all on the basis

of dry soil, and include total nitrogen, total carbon, phosphoric acid, and potash soluble in fifth normal nitric acid.

TABLE LIII.—Soil from Plots, Series No. 1.

	COMPOSITION IN 1895				COMPOSITION IN 1905			
	Total Nitrogen Per cent	Total Carbon Per cent	Phosphoric acid Parts per million Soluble in n/5 nitric acid	Potash Parts per million Soluble in n/5 nitric acid	Total Nitrogen Per cent	Total Carbon Per cent	Phosphoric acid Parts per million Soluble in n/5 nitric acid	Potash Parts per million Soluble in n/5 nitric acid
Plot No 1. Rotation: Wheat, 1 yr.; clover and timothy, 2 yrs.; oats, 1 yr.; corn. 1 yr	.229	3.00	39.54	195.0	.234	3.04	38.63	138.0
1. Plot No. 2. Rotation: Wheat, 1 yr.; bromus, 1 yr.; oats, 2 yr.; corn, 1 yr.	.231	3.06	51.76	195.2	.202	3.12	89.77	199.2
Plot No. 3. Rotation: Wheat, 1 yr.; timothy, 2 yrs.; oats, 1 yr.; corn, 1 yr.	.234	2.85	53.69	232.4	.217	2.92	41.61	156.7
2. Plot No. 4. Rotation: Wheat, 1 yr.; clover and timothy, 1 yr.; oats, 1 yr.; corn, 1 yr.	.218	2.90	19.16	....	.239	3.09	49.48	176.5
Plot No. 5. Rotation: Wheat, 1 yr.; clover and timothy, 2 yrs.; oats, 1 yr.; millet, 1 yr.	.222	.....	58.65	292.7	.247	.....	68.45	156.2
Plot No. 6. Rotation: Wheat 1 yr.; clover and timothy, 2 yrs.; oats, 1 yr., corn, 1 yr.	217	.....	57.58	....	.231	.....	60.04	163.3
Plot No. 7. Rotation: Wheat, 1 yr.; clover and timothy, 2 yrs.; oats, 1 yr.; mangles, 1 yr.	201	....	54 58	275.0	.204	.....	51 27	177.7
Plot No 8 Rotation: Wheat, 1 yr.; clover and timothy, 2 yrs.; oats, 1 yr ; rape. 1 yr.	201	....	75.11	165 6	206	.....	46.26	149.8
Plot No 9. Rotation: Wheat, 1 yr : clover and timothy, 2 yrs.; oats, 1 yr., potatoes, 1 yr	209	.....	76 26	149 7	.217	....	79 65	174 6
Plot No 10 Rotation: Wheat, 1 yr ; clover and timothy, 2 yrs ; oats, 1 yr.; sunflower. 1 yr.	198	2 72	74 63	155.5	.203	2.72	84.90	193.8
Plot No. 11. Rotation: Wheat, 1 yr ; clover and timothy, 2 yrs.; oats, 1 yr.; corn, 2 yrs.	.226	3.10	123 18	197.5	.226	2.99	117.00	126.0

1. In 1897 oats, and 1902 bromus.
2. Wheat in 1901 and clover 1904.

TABLE LIV.—Soils from Plots, Series No. 2.

	COMPOSITION IN 1895				COMPOSITION IN 1905			
	Total Nitrogen Per cent	Total Carbon Per cent	Phosphoric acid Parts per million Soluble in n/5 nitric acid	Potash Parts per million Soluble in n/5 nitric acid	Total Nitrogen Per cent	Total Carbon Per cent	Phosphoric acid Parts per million Soluble in n/5 nitric acid	Potash Parts per million Soluble in n/5 nitric acid
Plot No. 1. Rotation: Wheat, 1 yr.; clover and timothy, 2 yrs.; oats, 1 yr.; corn, 1 yr.	.239	.....	111 61	213 3	261	....	112 65	179 3
3. Plot No. 2. Rotation: Corn, 1 yr.; peas, 1 yr.; barley, 1 yr.; clover, 1 yr.	254	2 75	85 92	.....	273	2 95	78 98	141 6
Plot No. 3. Rotation: Barley, 1 yr.; oats, 1 yr.; timothy, 2 yrs.	*	2 70	90.49	361 5	*	2 81	71 74	150 9.
Plot No. 4. Rotation: Barley 1 yr.; oats, 1 yr.; timothy, 2 yrs.	*	2 58	.....	178 7	*	2 73	76 02	149 6
Plot No. 5. Rotation: Millet, 1 yr.; barley, 1 yr.; oats, 1 yr.; corn, 1 yr.	....	3 02	91.75	248 0	.225	3.02	79 01	101 3
Plot No. 6. Rotation: Wheat, 1 yr.; clover and timothy, 2 yrs.; oats, 1 yr.; corn, 1 yr.	.214	3 00	53.41	162 5	209	3.10	93 19	147 2
Plot No. 7. Rotation: Corn in hills continuously.	.219	2.94	54.81	172.4	.179	2 40	54 51	115.7
Plot No. 8. Rotation: Potatoes continuously.	.212	2.93	55.35	163.7	.178	2 27	57 24	105 4
Plot No. 9. Rotation: Mangles continuously.	.223	2.95	76.23	142.0	.190	2.50	73 72	....
Plot No. 10. Rotation: Peas, field, in drills continuously	.....	... .	110.03	....	.....	.....	75 99	128 2
Plot No. 11. Rotation: Wheat, 1 yr.; clover and timothy, 2 yrs.; oats, 1 yr.; corn, 1 yr.	.210	2.97	.....	.....	.219	3.05	311.00	173 8

* Plots in slight depression, results excluded.
3. Peas in 1898 and 1899, and corn in 1897.

TABLE LV.—Soil from Plots, Series No. 3.

	COMPOSITION IN 1895				COMPOSITION IN 1905			
	Total Nitrogen Per cent	Total Carbon Per cent	Phosphoric acid Parts per million Soluble in n/5 nitric acid	Potash Parts per million Soluble in n/6 nitric acid	Total Nitrogen Per cent	Total Carbon Per cent	Phosphoric acid Parts per million Soluble in n/5 nitric acid	Potash Parts per million Soluble in n/5 nitric acid
Plot No. 1. Rotation: Wheat, 1 yr; clover and timothy, 2 yrs; oats, 1 yr; corn, 1 yr	.215	.....	102 9	170.8	.232	.....	98 46	145.4
Plot No. 2. Rotation: Wheat continuously, fall: plow early.	.229	3.03	107.7	.....	.201	2 71	102 7	145.4
Plot No. 3. Rotation: Wheat continuously; sow 6 lbs. red clover with wheat.	.223	.....	101 0	191 8	.253	.....	78 0	141.4
4. Plot No. 4. Rotation: Wheat, 1 yr; clover, 1 yr; plow under second crop.	.215	2.51	79.25	.....	.250	3.34	73 97	141.5
4 Plot No. 5. Rotation. Wheat, 1 yr; clover, 1 yr, save second crop clover for seed or hay.	.215	2.93	112.6	165 3	.250	3 24	74 99	177.3
Plot No. 6. Rotation. Wheat, 1 yr; clover and timothy 2 yrs; oats, 1 yr; corn, 1 yr.	.220	3.02	86.20	195.26	.253	3.11	79.12	164.0
5. Plot No. 7. Rotation: Wheat, 1 yr; permanent pasture, red clover, timothy, red top, Kentucky blue grass, orchard grass, bromus, alsike and white clover.	.229	3 09	92.31	....	.233	3.16	56.21	143.6
5 Plot No. 8. Rotation: Wheat, 1 yr; permanent meadow, red clover, alsike clover, timothy, orchard grass, bromus.	.221	2.91	58.37	.....	.224	2.97	42.26	131.9
Plo No. 9. Rotation: Millet, 10 yrs. and some clover.	.217	.....	121.4	.....	.224	.....	124.4	143.4
Plot No 10. Rotation: Rape continuously, drill pasture off.	.211	3.00	81.84	.....	.....	3.10	76.70	153.4
Plot No. 11. Rotation: Wheat, 1 yr; clover and timothy 2 yrs; oats, 1 yr; corn 1 yr.	.220	.....	90.42	140.4	.257	.....	89.04	155 5

4. Wheat 1897 to 1900.
5. Wheat 1898.

TABLE LVI.—Soils from Plots, Series No. 4.

	COMPOSITION IN 1895				COMPOSITION IN 1905			
	Total Nitrogen Per cent	Total Carbon Per cent	Phosphoric acid Parts per million Soluble in n/5 nitric acid	Potash Parts per million Soluble in n/5 nitric acid	Total Nitrogen Per cent	Total Carbon Per cent	Phosphoric acid Parts per million Soluble in n/5 nitric acid	Potash Parts per million Soluble in n/5 nitric acid
Plot No. 1. Rotation: Wheat, 1 yr; clover and timothy, 2 yrs; oats, 1 yr, corn, 1 yr	.231	2 96	73 05	187.5	.253	3.32	76.07	175.2
6. Plot No. 2 Rotation: Wheat, 1 yr; clover and timothy, 2 yrs: oats 1 yr, green manure 1 yr; plow under crop of mixed oats early in summer late in fall a crop of rape.	.214	3 04	68.69	151.1	.239	3.45	42.14	150.5
Plot No 3 Rotation: Flax 1 yr; clover and timothy, 2 yrs; oats, 1 yr corn, 1 yr	.236	.....	105.4	243 2	.250	.....	71.56	149.2
7. Plot No. 4 Rotation: Barley, 1 yr; clover and timothy, 1 yr; pasture, 2 yrs. field pea hay, 1 yr.	.201	.....	102 5	231 0	.228	.....	48.25	132.0
8. Plot No 5. Rotation: Corn, 1 yr. rye and rape, 1 yr, barley, 1 yr, pasture, timothy, red and alsike clover, 3 yrs	.208	....	122 8	170 6	.230	.....	123.8	145.6
Plot No. 6. Rotation: Wheat 1 yr; clover and timothy, 2 yrs: oats, 1 yr; corn, 1 yr	.201	2 94	91 76	154 1	.215	3.04	76.58	108.3
9 Plot No 7. Rotation: Corn, 1 yr; rye, 1 yr; pasture, timothy, red and alsike clover, 2 yrs; barley 1 yr; peas, 1 yr.	.208	2 69	78 49	129 8	.218	2 89	72.71	115.3
Plot No. 8. Rotation: Barley, 1 yr; pasture, timothy, red and alsike clover, 2 yrs; corn, 1 yr	.209	.....	129.5	146.3	.225	.....	75 58	110.8
Plot No 9. Rotation: Wheat, 1 yr; timothy and clover, 2 yrs; oats, 1 yr, (tankage) corn.	.208	2 70	85 42	145 0	212	2 88	100 6	157.2
10. Plot No 10 Rotation: Wheat, 1 yr; timothy and clover, 2 yrs.	.209	2.68	94.19	160 6	.220	2.84	56.28	.....
Plot No. 11. Rotation: Wheat, 1 yr; clover and timothy, 2 yrs; oats, 1 yr; corn, 1 yr	.207	.....	115.9	155.3	.214	.....	96.14	146.8

6. No green manure, but oats in 1904. 7. Corn in 1900. 8. Rye in 1895.
9. Rye in 1895 and oat hay, 1902. 10. Corn, 1899.

Discussion of Results.

Control Rotation Plots. Twelve of the plots, Nos. 1, 6, and 11 of each of the four series, were designated as control plots and on all of these the same rotation was followed; namely: wheat, one year; clover and timothy, two years; oats, one year; corn (fertilized with eight tons of farm manure per acre), one year. The clover and timothy were seeded with the spring wheat, and usually a good stand of clover was secured the first year. The first year of meadow, clover predominated, and the second year timothy. It is to be noted that there was some clover produced during three of the five years. The nitrogen and carbon content of these twelve control plots, at the beginning and close of the ten year period, are given in the following table.

It is to be noted that ten of the twelve plots contained more nitrogen at the close than at the beginning of the experimental period, one contained the same amount, and one showed a slight loss. The average nitrogen content of the twelve plots in 1895 was .219 per cent, and in 1905 .233 per cent, a gain of .014 per cent. The maximum gain of .037 per cent was secured on Plot 11, Series III, while Plot 6, Series II, showed a loss of .005 per cent. Taken as a whole, the results show a slight gain of nitrogen during the ten years. This gain does not include the nitrogen removed as plant food by the crops, amounting to nearly 500 pounds per acre. The average gain of .014 per cent is greater than possible limits of error, and the larger portion of this can be attributed to no other cause than to an actual increase in the nitrogen content of the soils.

The accumulation of nitrogen in soils where clover and other legumes are grown, has been well established by Hellriegel and a number of other investigators. The extent to which soils may gain or lose nitrogen when grains and legumes are grown in rotations has not heretofore been extensively studied.

In these rotations, in which clover was grown during two years of the five, the nitrogen accumulated from at-

TABLE LVII.—Nitrogen and Carbon Content of Control Plots.

Series No.	Plot No.	NITROGEN		Carbon 1895	Per Cent 1905
		Per cent 1895	Per cent 1905		
I	1	.229	.234	3.00	3.04
I	6	.217	.231	....	.....
I	11	.226	.226	3.10	2.99
Average		.224	.230	3.05	3.01
II	1*	.239	.261	.....	.....
II	6	.214	.209	3 00	3.10
II	11	.210	.219	2.97	3.05
Average		.221	.229	2.99	3.07
III	1	.215	.232	.....	.....
III	6	.220	.253	3.02	3.11
III	11	.220	.257	.....	.....
Average		.218	.247	. .....	.....
IV	I	.231	.253	....	.....
IV	6	.201	.215	2.94	3 04
IV	11	.207	.214	.....	.....
Average		.213	.227	.....	....
General Average		.219	.233	3.00	3.06

*Plot in slight depression.

mospheric sources was sufficient to supply that required as plant food and to increase the store of total nitrogen in the soil to the extent of .014 of a per cent. It can be said that in these rotations the nitrogen content of the soil was fully maintained, and even to a slight extent increased.

The per cent of carbon obtained by combustion analyses also indicates that an equilibrium was maintained, as the percentage amounts at the beginning (3.00) and close (3.06) of the experimental period are practically the same. The use of the farm manure at the rate of eight tons once in five years, and the production of two

clover and timothy crops have been sufficient to maintain the humus and organic compounds of the soil. Any increase or decrease would be followed by a corresponding change in the content of the soil's carbon, inasmuch as humus is over fifty per cent carbon. The rotation fully maintained both the nitrogen and humus content of the soil.

At the beginning of the experiments the soils of the control plots contained an average of 178 parts per million of potash soluble in fifth normal nitric acid, and at the close 153 parts. The general tendency of the potassium compounds has been to become less soluble during the period of the rotations. While the loss was small, it was sufficient to show that the disintegration of minerals containing potash was not equal to the demands of the crop and loss through leaching and drainage. The potash soluble in fifth normal nitric acid was removed from the soil more rapidly than it was liberated by disintegration of the more complex potash containing minerals.

There was no material change in the solubility of the phosphate compounds during the experimental period, as measured by fifth normal nitric acid. In the case of five of the plots there were slight gains in solubility and seven of the plots showed losses. The changes in solubility of the phosphoric anhydrid were not sufficiently pronounced to allow definite conclusion being drawn. The phosphorus compounds of these plots do not appear to be as evenly distributed or as uniformly soluble as the potassium compounds. For a comparison of the fertilizer requirements of soils, as determined by field tests, and chemical methods involving the use of fifth normal nitric acid, the reader is referred to Bulletin No. 102 of this Station.

Rotation without Clover.—Where timothy alone was seeded (Plot 3, Series I), the rotation in other respects remaining the same as on the control plots, there was a loss of .017 per cent of nitrogen. This loss is about 10 per cent greater than the estimated amount removed as food by the crops during the experimental period. The

substitution of timothy for clover in the rotation resulted, at the end of ten years, in a difference of .031 per cent of nitrogen in favor of the clover. The carbon (humus) content of the soil was not appreciably affected by the substitution of timothy for clover.

Rotation with Clover and without Corn.—When potatoes and mangels were substituted for corn in the five year rotations (Plots 7 and 9, Series I), clover and timothy being grown as in the standard rotations and farm manure used, the nitrogen content of the soil was maintained. Corn, however, appears to conserve the nitrogen to a greater extent than roots, as the gain in the standard rotations with corn was .014 per cent and when roots were substituted .005 per cent .

Peas and Clover in a Rotation.—When both peas and clover were grown in a four course rotation (Plot 2, Series II) with corn and barley, there was a gain of .019 per cent of nitrogen and .2 per cent of carbon. When the rotation was lengthened to include rye, timothy being seeded with the clover and the land pastured (Plot 7, Series IV) the soil gained .01 per cent of nitrogen and .2 per cent of carbon. In a shorter rotation, where the rye was omitted and the land was one year in meadow (timothy and clover) and two years in pasture, corn, barley and pea hay also being grown, the soil gained .027 per cent of nitrogen. Peas and clover in a rotation appear to add the maximum amount of nitrogen to the soil when clover is produced more than one year.

Wheat and Clover in Rotation.—On a number of plots wheat and clover were combined to form rotations. The influence upon the nitrogen content of the soil is noted in the following table:

All of the combinations of wheat and clover show an increase of soil nitrogen, the gains in general being greater than in the standard five year rotations in which wheat and clover were grown with other crops. Clover, when used as green manure, has a marked effect in increasing the nitrogen content of the soil.

TABLE LVIII.—Nitrogen Content of Soils from Rotation Plots.

	1895	1905
Plot 3, Series III, wheat continuously, clover being sown each year with wheat as green manure	.223	.253
*Plot 4, Series III, wheat one year, clover 1 year, plow under second crop.	.215	.250
*Plot 5, Series III, wheat 1 year, clover 1 year, second crop used for seed.	.215	250
†Plot 10, Series IV, wheat 1 year, clover and timothy 2 years	.209	.220

* Wheat 1897 to 1900.
† Corn 1899.

Clover and Flax in Rotation.—Flax was substituted for wheat in one of the five-year rotations (Plot 3, Series IV). Clover and timothy were seeded with the flax; the land was left in meadow for two years and then oats were raised, followed by corn, manured at the rate of 8 tons of stable manure per acre. The substitution of the flax for the spring wheat had no effect upon the nitrogen content of the soil. The gain on the control plots with clover and wheat was .014 per cent nitrogen, and when flax was substituted for the wheat, the gain was also .014 per cent.

In 1896 a study was made of the draft of flax upon the land, and it was found that the fertility removed in a crop of flax yielding 15 bushels per acre was no greater than that removed by many other farm crops. An acre of corn removes more fertility than an acre of flax. The conclusion was reached that "Flax does not remove an excessive amount of fertility from the soil," and it was recommended that it should be grown in a rotation with clover and corn, and farm manure applied to the corn, when good crops of flax would be secured and the fertility of the soil would not be exhausted to any greater extent than if a grain crop were grown. (See Minn. Ex. Station Bulletin No. 47.) In this experiment it is to be noted that when such a system was followed the nitrogen content of the soil was maintained. Intelligent flax growing, in which flax forms one of the crops in a rotation, does not exhaust the fertility of the soil; it is when an attempt is made to grow flax too frequently on the same soil, or on soils that

are not properly prepared or adapted to its production, that poor yields result.

Green Manure.—On one of the rotation plots (No. 2, Series IV) a green manurial crop was substituted once during the ten years for the corn of the control rotation. This resulted in increasing the nitrogen content; the total gain during the ten years was .025 per cent, while the gain of the control plots was .014 per cent.

Permanent Pasture and Meadow.—A permanent meadow was seeded on Plot 8, Series III, and a permanent pasture on Plot 7, Series III. Difficulty was experienced in getting and keeping these plots in meadow and pasture. The soils practically maintained a nitrogen equilibrium without any material gain. Clover was seeded on both of these plots, but the non-legumes largely replaced the clover after the second year. It has been necessary to plow up and re-seed both plots.

Miscellaneous Rotation with Clover.—Clover was also grown on a number of plots in rotation with various miscellaneous crops. In all cases the soils increased in nitrogen content, as will be observed from the following table:

TABLE LIX.—Nitrogen Content of Soils from Miscellaneous Rotation Plots with Clover.

	1895	1905
Plot 5, Series IV, corn 1 year, rape and rye 1 year, barley 1 year, clover and timothy pasture 3 years, (rye 1895).	.208	.230
Plot 9, Series IV, wheat 1 year, clover and timothy 2 years, oats 1 year, corn 1 year, (tankage applied).	.208	.212
Plot 8, Series IV, barley 1 year, clover and timothy pasture 2 years, corn 1 year, (stable manure).	.209	.225
Plot 5, Series I, wheat 1 year, clover and timothy 2 years, oats 1 year, millet 1 year, (stable manure).	.222	.247
Plot 10, Series I, wheat 1 year, clover and timothy 2 years, oats 1 year, sun flower 1 year, (stable manure).	.198	.203
Plot 8, Series I, wheat 1 year, clover and timothy 2 years, rape 1 year, (stable manure).	.201	.206
Plot 9, Series III, millet hay 1 year, clover 1 year.	.217	.224

When clover was grown in a six course rotation (Plot 5, Series IV) there was a gain of .022 per cent of

nitrogen. When tankage was substituted for the stable manure of the standard rotation (Plot 9, Series IV) the soil nitrogen was not so well conserved as when farm manure was used. On Plots 5, 8 and 10, Series I, millet, rape and sunflowers were substituted for corn in the five course clover rotation, and a gain in nitrogen was secured in each case. There appears to be no large gain in nitrogen content from holding the land more than two years in meadow or pasture. The second year clover gives way to timothy and then the nitrogen previously accumulated may be drawn upon as plant food. On Plot 8, Series IV, barley and corn were grown and the land pastured two years; the gain of nitrogen to the soil was .016 per cent.

Continuous Cropping.—On four plots (No. 2, Series III, and Nos. 7, 8 and 9, Series II), wheat, corn, potatoes and mangels were grown continuously. The soils of all these plots lost nitrogen, as will be observed from the following table:

TABLE LX.—Nitrogen Content of Soils.

Series No.	Plot No.	Rotation	1895 Per Cent	1905 Per Cent	Loss Per Cent
III	2	Wheat, continuously	.229	.201	.028
II	7	Corn, "	.219	.179	.040
II	8	Potatoes, "	.212	.178	.034
II	9	Mangles, "	.223	.190	.033
Average,			.221	.187	.034

When wheat was grown continuously for ten years, there was a loss of .028 per cent of nitrogen from the soil, and in the case of corn the loss was .04 per cent. The average loss when the grain and roots were grown was .034 per cent. In these continuously cultivated plots no humus forming materials were added, and there was a reduction in the carbon content of over .5 of a per cent, equivalent to about 16 per cent of the total original carbon content of the soil. During the ten years of cultivation,

there has been a loss of about 16 per cent of both humus and nitrogen, and this was not confined to the surface six inches alone, less but appreciable loss having taken place from the subsoil.

It is estimated that an acre of the soil of these plots to a depth of six inches weighs in round numbers 2,100,000 pounds. The loss of nitrogen from the surface soil amounts to 714 pounds and from the subsoil to about 400, making a total loss of 1,100 pounds. It is estimated that about one-third of this nitrogen has been utilized as plant food, and about two-thirds have been lost.

The rapid decay of the vegetable matter (humus) of the soil has resulted in the liberation of more nitrogen than was utilized as plant food. During six or seven months of the year the process of nitrification—change of the humus nitrogen to soluble and available forms—goes on rapidly, and for about half of this time no crop occupies the land to absorb the nitrogen liberated by oxidation of the humus, and consequently a large portion of the available nitrogen, as nitrates formed as the result of nitrification, is lost in the drain waters, or volatile compounds of nitrogen are formed and liberated as gases. It is not possible to retain any large amount of nitrogen in the soil, except in the form of humus.

The factors which assist in rapid nitrification are: presence of lime and alkaline matter, and aeration of the soil such as is secured through continuous cultivation of one crop. The favorable mechanical condition of the soils of the continuously rotated plots, together with the requisite amount of lime, has been the main cause of the rapid nitrification of the humus, and the formation of nitrates through the workings of organisms. When wheat, corn, potatoes and mangels were grown in rotation with clover, new stores of nitrogen, derived from atmospheric sources, were added to the soil, and the rapid decay of the humus was checked. Continuous cropping is a destructive process, and the rotation of crops and the application of farm manures are constructive processes in humus building.

That the larger portion of the loss of nitrogen has been due to rapid nitrification is shown by investigations of Lawes and Gilbert, who studied the rate of nitrification in American soils collected at Winnipeg and other points in the Northwest Territory. These soils they exposed under laboratory conditions for periods of over a year (13 months), and at intervals determined the amounts of nitric nitrogen formed. As they state, these conditions were not strictly comparable with field conditions, but in a general way the results indicate the rapidity with which the nitrification process may take place in prairie soils. The results are given in Vol. VI, Rothamsted Memoirs, Field Experiments, page 417, from which the following condensed statement is made:

TABLE LXI.—Rapidity of Nitrification of Soils.

SOIL FROM	Lbs. of Nitrogen per Acre to depth of 1 ft.	Total Lbs. of Nitrogen as Nitric Acid formed		Per Cent of Total
		During period	During first Six Month	
Niverville	7,308	234.1	194.6	3.21
Brandon	5,236	250.1	179.2	4.78
Selkirk	17,304	653.1	466.6	3.77
Winnipeg	11,984	650.0	447.2	5.42
Average	10,458	447.4	321.9	4.29

It is to be noted, during a period of six months an average of 321.9 pounds of nitrogen as nitric acid, or nitrate nitrogen, was formed under the conditions of the experiment. At the same rate of nitrification, the amount of nitric nitrogen formed during the spring and summer months for ten years would amount to over 2,500 pounds per acre, or 25 per cent of the total soil nitrogen. This does not include the nitrogen in the form of nitrites and other soluble or volatile forms which are also known to be produced through oxidation of the humus.

When small grains are grown on new land, the loss of nitrogen is undoubtedly greater than when grown on

soil that has been under long cultivation. In old soil the humus becomes less active and nitrification does not take place so readily. The rate of nitrification and the amount of nitrogen added to the soils by judicious rotations with legumes can be controlled largely by the farmer. A loss of 1,100 pounds of nitrogen in ten years from soils where wheat, corn, potatoes and mangles were grown continuously, seriously affected the permanent crop producing capacity. Although the soils of these plots still contain a comparatively large amount of nitrogen, this excessive loss caused by continuous cropping was unnecessary and did not occur on the plots where the crops were rotated with clover.

In former investigations, the loss of nitrogen from the soil, to a depth of nine inches, when corn and small grains were grown continuously, ranged from 1,400 to 2,000 pounds per acre in twelve years. Both the former and the present investigations show that continuous cropping to small grains and roots results in depletion of the soil nitrogen, and by far the larger portion is not used as plant food but is lost through rapid decay of the humus and liberation of its nitrogen in volatile and soluble forms.

The losses of organic matter (humus compounds) from the soils have also been large. The analyses show a decline of .5 per cent in the carbon content in ten years. It is estimated that during the ten years the soils upon which the grains and roots have been raised continuously have sustained a loss of over one per cent of organic compounds, equivalent to over 20,000 pounds per acre, or an annual loss of one ton.

Gains of Nitrogen. When wheat was grown in rotation with clover and corn, as in the standard rotation, the average gain of nitrogen to the soil was .014 per cent, equivalent to about 300 pounds in ten years. The maximum gain when clover was grown, .037 per cent on Plot 11, Series III, was equivalent to about 775 pounds, while Plot 6, Series II, showed a loss of .005 per cent, or 100 pounds. With the exception noted, gains are recorded

on all of the plots where clover was grown. The gains and losses per acre of nitrogen and carbon are calculated by multiplying the per cent of nitrogen, as obtained by analyses, by the estimated weight per acre of the soil to a depth of six inches. As previously stated, the per cent of nitrogen can be accurately determined, but the weight per acre can only be approximated. In making the calculations, it was deemed best to use the factors representing the maximum apparent specific gravity as determined from the maximum weight per cubic foot of the soil (dry) in situ, and from the computed values obtained from the absolute specific gravity and the apparent specific gravity of the moderately compacted in which the per cent of pore space is known. It is estimated that an acre of the soils of these plots to a depth of six inches weighs under the conditions stated 2,100,000 pounds, in round numbers. Warington states that "nine inches depth of arable soil (clay or loam) will weigh when perfectly dry 3,000,000 to 3,500,000 pounds per acre. King, in the 17th annual report of the Wisconsin Station, page 209, states that three inches depth of stirred soil represents one-fourth of an acre foot, or 100,000,000 pounds, in round numbers.

SUMMARY.

The analyses of the soils of the forty-four experimental plots at the beginning and the close of the ten year period showed:

(1) The maximum amount of nitrogen was lost when the soils were cropped exclusively to wheat, corn, potatoes and mangels. When these crops were grown continuously there was an average loss of .034 per cent of nitrogen, equivalent to 1,100 pounds per acre. In the case of wheat two-thirds of this nitrogen were not utilized as plant food but were lost by the rapid decay of the humus with the formation of soluble and volatile nitrogen compounds. When the crops were grown continuously the soils lost .5 of a per cent of carbon, representing over one per cent of humus, or 20,000 pounds, equivalent to an annual loss of one ton per acre.

(2) There was an average gain of .014 per cent of nitrogen, equivalent to about 300 pounds per acre, in the case of twelve standard rotations, consisting of wheat one year, clover and timothy two years, oats one year, and corn one year, manured with stable manure at the rate of eight tons per acre. From one of the twelve plots there was a small loss of nitrogen. The results, taken as a whole, show the nitrogen content is maintained when clover is grown two years in a five course rotation, and then the

application of nitrogen containing fertilizers is unnecessary. In practically all the rotations where clover was grown, gains of nitrogen were secured. There were no great differences in gains of nitrogen that could be attributed to the combination of any special crops with clover. Any substitution of crops in the rotation could be made without materially affecting the nitrogen content of the soil, provided clover was retained. When the crops were rotated, the carbon and humus content of the soil was maintained and in some cases slightly increased. The results show that wheat, corn, oats, barley, flax, rape, potatoes, mangels, millet, bromus and timothy can be grown with clover in three, four, five or six year rotations without loss from the soil of either nitrogen or humus. By rotations with clover, the nitrogen content was conserved, and in some cases slightly increased. The gains and losses of nitrogen are practically under the control of the cultivator.

(3) In the rotations where timothy and non-legumes were substituted for clover, a loss of nitrogen occurred, but the carbon (and humus) content was maintained. The conservation of the humus prevented rapid nitrification, and the loss of nitrogen from the soil only slightly exceeded that removed by the crops.

(4) The potash compounds of the soil were less soluble at the close than at the beginning of the ten year experimental period. The formation of soluble potash compounds from the decay of the potash minerals did not keep pace with the amount removed as plant food and that lost in soluble forms in the drain waters.

(5) Systems of rotation, in which clover (and other legumes) form an essential part and in which farm manures are used, should be practiced to prevent depletion of the nitrogen and humus of soils, because the humus takes such an important part, chemically, physically and bacteriologically, in maintaing the fertility.

Correction to Bulletin No. 102.

On Plot No. 3, 40 pounds of nitrate of soda, read 32 pounds.

Correction to Bulletin No. 80.

Page 165. In the fifth column, nitrogen free extract, read 39.40, not 38.77. Page 172, Table 77, nitrogen free extract, read 37.48, not 37.03.

Corrections to Bulletin No. 65.

Page 55. Subsoil No. 572, volatile, read 10.30, not 1.30.
Page 56. Subsoil No. 570, add medium sand, 7.43.
Page 56. Subsoil No. 538, silt, read 20.99, not 22.99.

Corrections to Bulletin No. 63.

Page 500. No. 1265, nitrogen free extract, 70.39, not 71.49.
Page 528. Sample 2, total nitrogen .359, not 369.

Corrections to Annual Report.

Page 180c . Sample 1, alfalfa hay, nitrogen free extract, read 37.50, not 34.47, and also sample 8, read 32.30, not 32.09.

INDEX

A.

Page

Abortion, infections report of work with XXI
Agricultural Chemistry and Soils, report of division X
Agricultural Committee, list of II
Agriculture, report of division IX
Analyses of feeding stuffs 148
Animal Husbandry, report of division X
Animal Nutrition and Dairy Husbandry, report of division XI
Arrangement of fields 95
Autopsy records 44, 53

B.

Board of Regents, list of II
Botany and Vegetable Pathology, report of XV
Bread making value of the flours 31
Breads made from wheats grown with and without fertilizers .. 33
Breed characters or corn 239
Breeding, corn, principles of 200
Breeding of corn in Minnesota 192
Bulletins, list of published during year IV
published XXV

C.

Caterpillars, inflating and mounting 140
Centgener notes on corn breeding 218
selection 218
Chemical methods, a comparison of with field tests for determining the fertilizer requirements of soils 35
Clover, in rotation of crops 321, 349, 351, 352
Coleoptera 130
Commercial fertilizers 291
Composition of wheat raised on experiment plots 28
Concentrates, nutriment in 166
Continued cropping, experiments with 353
Corn and wheat, fertilizer tests with 1
breed characters of 239
breeding, centgener notes on 218
of in Minnesota 192
plot 208
possibilities in Minnesota 177
principles of 200
recapitulation 252
registry system 216
cost of producing 86
ear notes 223
selection 223
factors which influence yield of 197
field observations in hogging off 104

Page
Corn, formation of ears 192
foundation plot 203
stocks of 202
hogging off, questions pertaining to..... 71
what it means 69
influence of environment on quality of..... 199
in rotation of crops 350
kind to grow 104
lack in uniformity and type of..... 179
nature of pollination 182
pedigree chart 236
of 229
pollination and formation of ears..... 180
rules and explanation of points on..... 243
sampling and shrinkage of in pork production experiments 73
score card 237
points on 242
selecting ears 203
kernels for planting 227
vitality of 240
Cows, Jersey, record of during the 1st and 2nd sixty-day periods 165
rank of based upon nutriment required for the production of a pound of butter fat..... 161
milk solids 163
Crop rotation, clover in 321
effect on fertility and composition of soil..... 328
experiments, history of forty-four plots.....301-327
flax 326
improves condition of soil..... 287
millet as a nurse crop..... 322
pasture and meadow..... 352
practical 295
rape 322
size of fields 296-298
use of green manure in..... 352
weediness 320
Cropping, continued, experiments with..... 353
Crops, classes of 292
grass, importance of 299
rotation of 283
discussion of results 347
effect on plant food..... 285
former results and conclusions..... 330
profits and decrease of acreage..... 300
summary 281, 357

D.

Daily average products yielded by each cow..... 152
group..... 156
of dry matter and nutrients consumed by each cow 152
groupe 156
Dairy cow demonstration, summary of result.....168-169
Dairy Husbandry and Animal Nutrition, report of division..... XI
Dairy products, daily average yielded by each cow..... 152
group..... 156
yielded and food consumed daily per 1,000 lbs. live weight 167
Digestion coefficients 151
Diptera 130
Director of Experiment Station, report of..... V
Dissemination of tuberculosis by the manure of infected cattle.. 39-58

E.

	Page
Drainage	298
Entomology, report of division	XII
Experiment corps, list of	II
Experiments in pork production, summary	67
Experiments with fertilizers at Langdon	5
University Farm	4
Experiments with wheat at Benson	7
Montevideo	9
Renville	11
St. James	6
Starbuck	7
Waltham	6

F.

Factors which influence yield of corn	197
Feed analyses, results of	148
consumed by the Jersey and Shorthorn cows	152
Swiss and Holstein cows	151
value of pastures as	87
Feeding in field, effect upon subsequent gain	80
standard	157
stuffs, analyses of	148
Feeds and adjuncts in pork production experiments	74
Fences, cost of	92
life of	91
temporary for hogs	89
Fencing, average annual cost of	95
for pigs	75
Fertilizer experiments at Ada	16
Amboy	20
Austin	21
Benson	7
Breckenridge	17
Brownsdale	21
Brown's Valley	17
Dover	18
Elk River	20
Fairmont	20
Grand Rapids	14
Hagen	21
Hanley Falls	22
Langdon	5
Litchfield	12
Lynd	12
Montevideo	9
New Ulm	18
Northfield	19
Park Rapids	14
Pine Island	18
Pipestone	13
Randall	15
Renville	11
St. James	6
Starbuck	7
Ulen	16
University Farm	4
Vining	15
Waltham	6
Warren	16

Page

Fertilizer experiments at Zumbro Falls 19
summary 22
requirements of soils, a comparison of chemical methods with field tests for determining..... 35
tests, directions for making, with wheat..... 1
with wheat and corn..... 1
trial on large plots with wheat..... 8
small plots with wheat..... 8
Fertilizers, commercial 291
influence of upon the composition and quality of wheat 24
influence of upon the weight per bushel of wheat, and character of the kernels..... 25
Field management of swine..... 85
Field observations in hogging off corn..... 104
Field, size of to be hogged off at one time..... 106
Fields, arrangement of 95
size of under crop rotation.....296-298
Financial statement VII
Flax 351
value in crop rotation..... 326
Flax wilt 327
Flours, bread making value of..... 31
Food consumed and dairy, products yielded daily per 1,000 lbs. live weight 167
Forage and grain, valuation of..... 148
Forestry and Horticulture, report of division..... XIV
Formation and pollination of corn ears..... 180
of corn ears 192
Foundation stocks of corn..... 202

G.

Grain and forage, valuation of..... 148
aphids, field work with..... 267
in Minnesota 267
natural enemies of..... 273
Grass crops, importance of..... 299
"Green Bug" and other grain aphids, general view of conditions in Minnesota 257
history of in southern states..... 263
how it reached Minnesota..... 265
life history 265
natural enemies of 273
protective measures against..... 277
Green manure, use of in crop rotation..... 352

H.

Hemiptera 129
History of the green bug in the southern states..... 263
Hog cholera, Carling farm experiment..... XVII
report of work with..... XVI
University Farm outbreak..... XVI
Hogging off corn, field observations in..... 104
letters from farmers on.....109-119
questions pertaining to..... 71
what it means..... 69

Page

Hogs, amount of pasture needed for 97
marketing of 83
time to turn into cornfields 106
watering of 105
Horticulture and Forestry, report of division XIV
Hymenoptera 132

I.

Infectious abortion, report of work with XXI
Influence of environment on quality of corn 199
Insect, definition of 125
Insect orders defined 126-132
Insects, baiting and night collecting 136
collecting paraphernalia 132-135
pinning, spreading, inflating, labeling, etc 137
relation of to the nation's wealth 2nd 119
relaxing dried ones 143

L.

Larvæ, rearing of 141
Lepidoptera 131
Letter of transmittal III
Letters from farmers on hogging off corn 109-119

M.

Marketing the hogs 83
Meadow and pasture in rotation of crops 352
Millet as a nurse crop 322

N.

Nasal secretion, virulence of 59
Neuroptera 127
Nitrate of soda, forms of nitrogen in wheat fertilized with 29
Nitrogen, forms of in wheat fertilized with nitrate of soda 29
gains of in rotation 356
Northeast Experiment Farm, report of XXII
Northwest Experiment Farm, report of XXIV
Nutrients consumed and disposition made of them 158
Nutriment in concentrates 166
roughage 165
Nutriments consumed and relation to dairy products yielded ... 160

O.

Odonata 127
Orthoptera 128

P.

Pastures, amount of needed for hogs 97
and meadow in rotation of crops 352
kind of 88
permanent 88
value of as feed 87
Peas in rotation of crops 350
Phosphoric acid and potash of the soil soluble in fifth normal nitric acid 36

Page

Pigs, fencing for 75
nature of in pork production experiments..... 73
shelter for 76, 107
size to use in hogging off corn..... 104
Plant food, effected by rotation of crops..... 285
Pollination and formation of corn ears..... 180
of corn, nature of..... 182
Pork production experiment, detail of..... 71
results 77
summary 67
Potash and phosphoric acid of the soil soluble in fifth normal nitric acid 36
Principles of corn breeding..... 200

R.

Rape, value in crop rotation..... 322
Registry system of corn breeding..... 216
Relation of insects to the nation's wealth.....2nd 119
nutriment to product 147
Report of the Director of the Experiment Station..... V
Results of feed analyses 148
pork production experiments..... 77
Rotation experiments, history of forty-four plots.....301-327
Rotation of crops..... 283
discussion of results 347
effect on fertility and composition of soil.... 328
plant food 285
former results and conclusions..... 330
improves condition of soil..... 287
practical 295
profits and decrease of acreage..... 300
size of fields 296-298
summary 281, 357
use of green manure in..... 352
with clover 321, 349, 351, 352
corn 350
flax 326
millet as a nurse crop..... 322
peas 350
pasture and meadow..... 352
rape 322
timothy 349
wheat 350
Roughage, nutriment in..... 165
Rules and explanation of points on corn..... 243

S.

Sampling and shrinkage of corn in pork production experiment 73
Score card for seed corn ears..... 238
points on corn 242
Secretion, nasal, virulence of..... 59
Seed corn ears, score card for..... 238
Selecting corn ears 203
kernels of corn for planting..... 227
Shelter for pigs 76, 107
Siphonaptera 130
Size of field to be hogged off at one time..... 106
Soil, condition of improved by crop rotation..... 287